Volume 29 FEBRUARY, 1945 Number 2

# BULLETIN
## *of the*
# American Association *of* Petroleum Geologists

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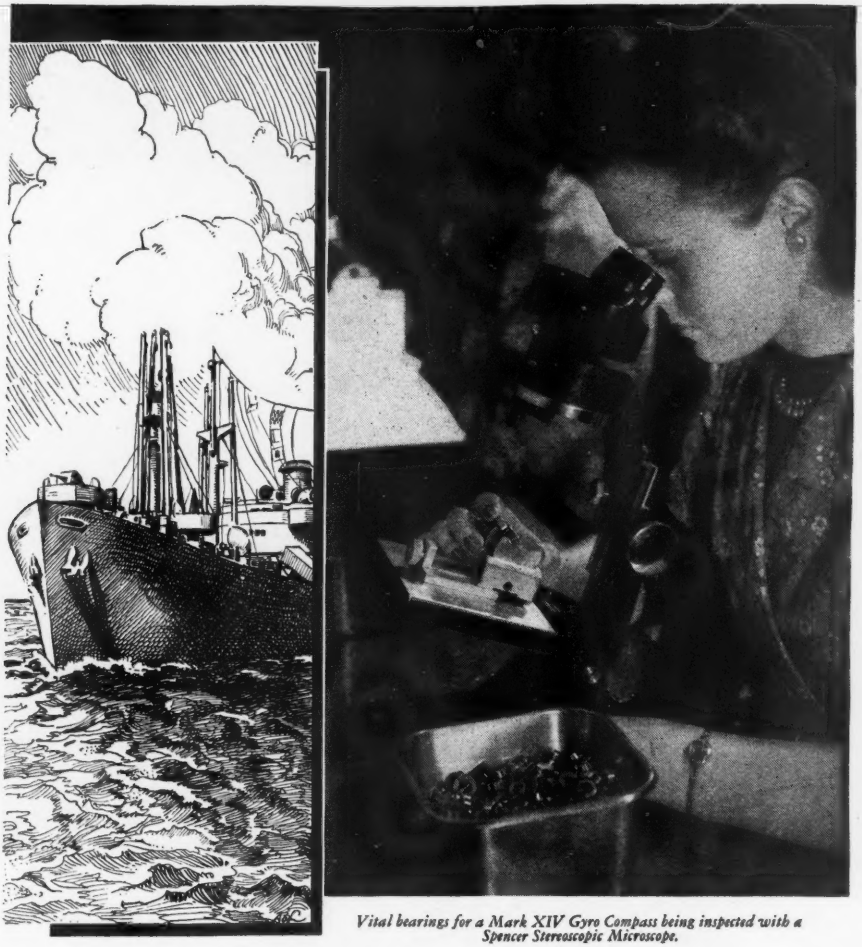

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By Nicholas A. Rose and W. H. Alexander, Jr.

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# BULLETIN
## *of the*
# AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

FEBRUARY, 1945

## CLASSIFICATION OF MISSISSIPPIAN AND PENNSYLVANIAN ROCKS OF NORTH AMERICA[1]

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### FOREWORD

As a logical sequel to review of the classification of Permian rocks[9] by a subcommittee on the Permian, the Association committee on geologic names and correlations at its March, 1940, meeting directed that a similar investigation and report be made of the classification of the Mississippian and Pennsylvanian. Geologists at that time were confronted with the choice of

(1) classifying these rocks as the Carboniferous system in harmony with general practice outside the United States,

(2) following the United States Geological Survey usage of classifying these rocks together with the Permian as the Carboniferous system (Permian was excluded late in 1941), or

(3) departing from these traditional customs in favor of the opinion of many geologists, particularly in the United States, that rocks of Mississippian and

[1] Manuscript received, November 17, 1944.

[2] President, Anzac Oil Corporation.

[3] Director, Oklahoma Geological Survey.

[4] Division geologist, Gulf Refining Company, Indianapolis, Indiana; on leave, Lieutenant Colonel, United States Army.

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[6] Professor of geology, The Johns Hopkins University; on leave, for geological work in Peru.

[7] Professor of geology, University of Wyoming, State geologist and director, Geological Survey of Wyoming.

[8] Petroleum geologist.

[9] C. W. Tomlinson *et al.*, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 337–58.

Pennsylvanian age are more appropriately classified as two independent geologic systems and geologic periods, the term Carboniferous being either archaic or of use only where these rocks are not differentiated.

This third choice has for many years been advocated by some geologists, as shown by correspondence from James Hall[9a] to Charles Dana in 1855, and has now become the predominating practice in the United States among the State geological surveys, authors of text books on historical geology, and geologists of the oil and coal industries. The following report briefly reviews these diverse usages and the related problems, such as type sections, standard sections, section of reference, series designation and interregional correlations.

A general premise under which efforts of the Carboniferous subcommittee have been carried forward is that large practical benefit should be derived from eventual agreement in

(1) choosing names and boundaries of at least the major divisions of geologic time and the stratigraphic record, particularly the periods and systems, epochs and series;

(2) designating type sections and type areas where such divisions were first established;

(3) recognizing specially complete or otherwise important sections as supplementary regional sections of reference, with division names in accord with local usage but with boundaries coördinated with the standard sections; and

(4) establishing interregional correlations.

Moore, Dott, and Thomas have given much study to these problems in carrying out their official duties as directors of the State geological surveys of Kansas, Oklahoma, and Wyoming, respectively. Moore, Newell, and Thomas have been engaged in teaching geology at the Universities of Kansas, Wisconsin, and Wyoming. Cheney, Hake, and Tomlinson in their work as petroleum geologists, have for many years specialized in the study of Pennsylvanian and Mississippian rocks. The subcommittee has enlisted the help of many geologists and has given much attention to pertinent literature published in the United States and elsewhere. In both cases the list is too extensive to enumerate in full. The subcommittee is indebted to the following for assistance given through correspondence and attendance at meetings of the subcommittee.

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[9a] John M. Clarke, *Life of James Hall* (1921).

This acknowledgment does not signify that the persons named give their endorsement to the following report, nor does the report itself necessarily express the fully considered opinion of all members of the subcommittee, three of whom for many months have devoted their attention to special assignments in the war effort, from Alaska to Peru.

### STRATIGRAPHIC PRINCIPLES

The subcommittee has reviewed the conclusions of the Permian subcommittee as to principles of stratigraphic classification and endorses those bearing on definition of a geologic system and its major divisions.[10]

Both subcommittees have held that to permit progress toward well ordered, soundly based differentiation of geologic time and rock sequences, objective facts must be given greater weight than usage and priority. Question as to the relative importance of these factors in determining stratigraphic nomenclature was submitted late in 1941 to 28 State geological surveys, no comment as to judgments of the subcommittee being made. Answers to this inquiry are tabulated as follows.

OPINIONS OF STATE GEOLOGICAL SURVEYS ON RELATIVE IMPORTANCE OF FACTORS AFFECTING STRATIGRAPHIC NOMENCLATURE

| | *Priority* | *Usage* | *Objective Facts* |
|---|---|---|---|
| Most important | 4 | 6 | 13 |
| Next in importance | 3 | 14 | 6 |
| Least important | 16 | 3 | 4 |

## PART I

### CARBONIFEROUS SYSTEM VERSUS MISSISSIPPIAN AND PENNSYLVANIAN SYSTEMS

The questionnaire just referred to was sent to State geological surveys most concerned with the Carboniferous rocks because of the presence of these rocks within their State boundaries. The State geological surveys necessarily give close attention to problems of classification, reflect prevailing geological thought within their particular areas, are reasonably flexible, and are responsive to current study of geologic data. Response to this questionnaire from the Surveys, accordingly, should fairly indicate the trend in usage in the United States. The following gives a chronological record of how these 28 State surveys have classified the Mississippian and Pennsylvanian rocks.

CLASSIFICATION OF MISSISSIPPIAN AND PENNSYLVANIAN ROCKS BY STATE GEOLOGICAL SURVEYS

| *Year* | *As Series* | *As Systems* | *As "Subsystems"* |
|---|---|---|---|
| 1908 | 26 | 2 | 0 |
| 1916 | 17 | 8 | 1 (Michigan) |
| 1924 | 15 | 13 | 0 |
| 1932 | 6 | 22 | 0 |
| 1940 | 7 | 21 | 0 |
| 1942 | 2 | 24 | 2 |
| 1944 | 2* | 25 | 1 (Nebraska) |

* Alabama and Nevada. The Alabama Survey follows classification used by Charles Butts in "Geology of Alabama" published by the Alabama Survey in 1926, *Special Report No. 12*. In 1944 Charles Butts states that for a number of years he has favored adoption of Mississippian and Pennsylvanian *systems*.

[10] C. W. Tomlinson *et al.*, *op. cit.*

———, "Technique of Stratigraphic Nomenclature," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 2038–46.

The results show a well sustained trend toward change from series to system as the assigned rank for Mississippian and Pennsylvanian rocks. The evidence for this change must have appeared convincing for changes of classification undoubtedly cause considerable annoyance and inconvenience to such organizations with their publications and museum displays. It will be recalled that this innovation was first formally advocated by Chamberlin and Salisbury.[11] Extensive studies, supported by paleontologic data marshaled by Professor Stuart Weller and others, persuaded Chamberlin and Salisbury that classification of these rocks as one system was inconsistent and illogical. A questionnaire sent out by the United States Geological Survey in 1915 disclosed that by then 33 specialists favored this change and 26 opposed it. Comparison with the foregoing figures indicates some reservation on the part of the State surveys as compared with opinion of individual geologists. Deference to international usage and greater need of fixed policy and conservatism may well explain the continued use of Carboniferous system by the United States Geological Survey, many members of which are known to prefer classification of these rocks as two systems.

*Objective facts.*—The subcommittee unanimously agrees that the Mississippian and Pennsylvanian are each fully qualified to rank as a geologic system or period. Applied to North America this conclusion agrees with (1) the usage of most of the State geological surveys, (2) the opinion of most of the specialists in upper Paleozoic paleontology and stratigraphy, (3) most of the university and college teaching, and (4) most of the text books written since 1906. Reference is made to those text books on historical geology for more complete discussion of the physical evidence that has induced geologists in North America to depart from the earlier practice of classifying these rocks as the Carboniferous system.

Accumulating evidence has given more and more support to the thesis that the Mississippian and Pennsylvanian divisions each equals or exceeds the average geologic system or period in the following respects: (1) distinctive organic developments, including major advances in some life forms; (2) the rock sequences are distinctive in character and great in volume; (3) duration; (4) pronounced structural adjustments occurred over large areas; (5) regional unconformities of major importance are present within and at the base and top of each of these systems; (6) areal extent of outcrop.

Because of their great economic importance it is essential that the Pennsylvanian rocks, in particular, be given prominence and separate designation in geologic mapping. The coal, oil, gas, ceramic clays, and other minerals found in rocks of Pennsylvanian age greatly exceed the value of the mineral resources found in any other system. This appears true not only for North America but for the earth as a whole.

*Usage.*—Recently more than half of the world literature on rocks of Mississippian and Pennsylvanian or Carboniferous age has treated these rocks as two

[11] T. C. Chamberlin and R. D. Salisbury, *Geology*, Vol. 2, *Earth History* (1906), p. 539.

systems. However, only a few authors residing outside the United States have adopted this practice. Lack of concurrence abroad may be due in part to a hesitancy to accept systems or systemic names originating outside Europe. Since systems are time-rock divisions to be fitted into one common time scale for all continents, the location of the type area of a system seems to be of little consequence once interregional correlations are established as they now seem to be for rocks of Mississippian and Pennsylvanian age between North America and various parts of the world. Uniform world-wide classification by periods and systems is desirable, and persistent study and effort will no doubt bring world agreement on the definition and names of these major divisions. Being designed for world-wide application, a system may properly take its name and have its type area in any continent where it first became well established.

*Priority.*—Concerted action toward dividing Carboniferous rocks into two systems has come mainly from North America. The names Mississippian and Pennsylvanian have long been applied to these two divisions which reveal especially complete development in this continent. When formal proposal was made in 1906 that these divisions be elevated to systemic rank the name Mississippian had been in use 45 years (A. Winchell, 1861) and Pennsylvanian for 15 years (H. S. Williams, 1891). Now, for 83 and 53 years, respectively, these names have filled a need for suitable geographically derived terms to displace the earlier rock terms Lower Carboniferous or Carboniferous Limestone, and Upper Carboniferous or Coal-measures, as well as the too inclusive name Carboniferous system.

As a practical matter, both the Mississippian and Pennsylvanian rock sequences are of such character and arrangement that systemic rank for each of these major divisions is needed to provide proper subordinate subdivisions of classification. It is, of course, customary and useful to give a formal name to each widely occurring, important rock unit. According to rules of stratigraphic nomenclature such minor rock units are classified as *members*. More comprehensive rock divisions, characterized by common features of lithology and fauna or flora, and constituting convenient divisions for mapping, are called *formations*. Two or more formations having generally similar lithologic characteristics or fossil content may be referred to collectively as a *group*. Formations and groups occurring between major faunal and diastrophic breaks are combined into a *series*, a provincial major time-rock division. Two or more related series constitute a *system*. Most geologists engaged in the study of Mississippian and Pennsylvanian rocks of North America hold that proper classification of these rocks requires division into a total of not less than seven series. Many geologists, including a majority of those who were assigned the task of preparing this report, believe that objective facts and usage support dividing the Mississippian rocks into four series and the Pennsylvanian rocks into six series; also that the Mississippian and Pennsylvanian divisions are so distinct and exhibit such important developments geologically that they must necessarily be classified as two major chapters or periods of earth history.

The Mississippian rocks of North America present a remarkably complete record of paleontological and depositional developments of this period. The Pennsylvanian rocks of North America appear to be one of the most complete in the world for this division of geologic time. For these various reasons, the use of North American classification and North American names for these systems is especially fitting and proper.

Brief review of the origin and modification in usage of the name Carboniferous appears appropriate. Initial use of this name is credited to the Reverend W. D. Conybeare and W. Phillips[12] in 1822. These authors used "Carboniferous" as an "epithet," as they called it, for the third (or medial) of five "orders," of which the oldest is now classified as pre-Cambrian, and the youngest as Tertiary and Quaternary. These five "orders" were differentiated mainly by their lithologic and structural relationships, the third being the Carboniferous rocks, comprising in downward order:

a. Coal-measures
b. Carboniferous limestone
c. Old red sandstone.

The rocks of the next older or "submedial order" are now known as the Cambrian, Ordovician and Silurian systems. In 1839 the Reverend A. Sedgwick and R. I. Murchison appropriately assigned the "Old Red sandstone" to the Devonian system. That divisions "a" and "b" were not then classified as separate systems now appears unfortunate and illogical. In most geological literature since 1822 these divisions of the "medial order" have in fact been accorded distinctive and separate treatment comparable with the Devonian and Permian. For example, the well prepared *Tabular View of Characteristic British Fossils, Stratigraphically Arranged*, published in 1853 by the Society for Promoting Christian Knowledge (London), gave separate and equal chart space to the fossils of the (1) Permian, (2) Coal-measures, (3) Carboniferous or Mountain Limestone and Carboniferous Shale and (4) Devonian. Quite regrettably, European and American usage continues to differ in the names and rank of the second and third of these four divisions. This subcommittee agrees with those who believe that ever widening studies support the logic of classifying these rocks as independent systems. Selection of appropriate geographically derived names for world usage is needed to replace Lower Carboniferous and Upper Carboniferous. Such names have been adopted and generally so used in North America for many years with nearly constant meaning, namely, the Mississippian system and Pennsylvanian system. In Europe a Lower Carboniferous with variable limitations has been called Dinantian; Middle and Upper, or Upper Carboniferous have been variously named.

Present usage in Europe evidently continues diverse. Those European geologists who divide the Carboniferous into two series differ among themselves in

[12] M. Grace Wilmarth, "Geologic Time Classification," *U. S. Geol. Survey Bull. 769* (1925), pp. 65–68.

## CHART I

COMPARISON OF CLASSIFICATION AND CORRELATION OF ROCKS OF MISSISSIPPIAN AND PENNSYLVANIAN AGE OF NORTH AMERICA AND EUROPE

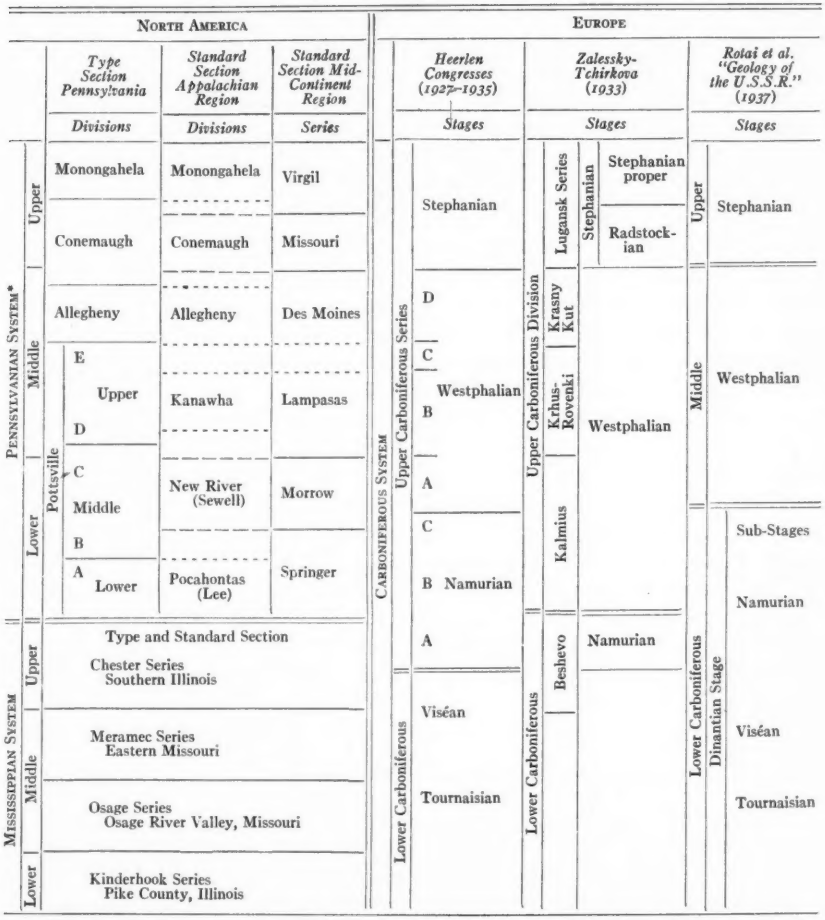



CHART I.—Type and standard sections of Mississippian and Pennsylvanian rocks of North America compared with divergent classification of equivalent rocks in Europe. See Table 1 of guidebook "The Southern Excursion, Donetz Coal Basin" (1937), XVII International Geological Congress. Broken lines signify alternative location of boundaries.
* Type localities are shown in Chart II.

placing the boundary between Lower and Upper Carboniferous at (1) base of Namurian, (2) within the Namurian, or (3) top of Namurian. Other European geologists divide the Carboniferous into three divisions or series as shown in Chart I.

Early adoption of uniform classification of the Carboniferous rocks in Europe

appears most improbable. Contrasted to this, there is almost complete agreement among the geologists of the 28 State surveys and others in the United States that these rocks should be divided into two systems, separated by the very extensive unconformity between Chester or older Mississippian rocks and Pottsville or younger Pennsylvanian strata. That "the pre-Pennsylvanian unconformity is one of the most widespread unconformities in all the Paleozoic rocks of North America," has long been recognized.[13] Only in very limited areas are rocks of earliest Pottsville age found resting on rocks of latest Chester age. The extent of this unconformity in the United States has been clearly shown by Levorsen.[14]

That the break between the Mississippian and Pennsylvanian is of world-wide significance also is indicated by the geologic record in other continents. Ting and Grabau[15] state that "the Carboniferous of China naturally falls into two divisions comparable with the Mississippian and Pennsylvanian of North America." Plate 1 of their report shows an extensive overlap of older beds by Pennsylvanian equivalents. According to Lee[16] the occurrence of *Fusulinella* and *Fusulina* is particularly widespread which further indicates conditions comparable with those of the Pennsylvanian of the United States.

Studies in South America, Africa, and Australia show that the Mississippian and Pennsylvanian equivalents are separable there also and that the major divisions of these systems are recognizable much as in the Northern Hemisphere.[17]

Paleontologists generally agree in correlating the divisions of the North American and European Late Paleozoic sections. Based partly on their conclusions, it is evident that the unconformity so widely recognized in the United States between Mississippian and Pennsylvanian rocks is represented by important hiatuses elsewhere. In this connection, attention may be called to the pronounced floral changes between zones A and B of Dix,[18] and the correlation between steps in evolution of goniatites,[19] and significant orogenic movements (Erz-

[13] G. H. Girty, "The Bend Formation and Its Correlation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), p. 74.

[14] A. I. Levorsen, "Pennsylvanian Overlap in United States," *ibid.*, Vol. 15, No. 2 (1931), pp. 113–48.

[15] V. K. Ting and A. W. Grabau, "Carboniferous of China and Its Bearing on the Classification of the Mississippian and Pennsylvanian," *Rept. XVI Internat. Geol. Cong.*, Vol. 1 (1936), pp. 555–71.

[16] J. S. Lee, *The Geology of China*, Thos. Murby & Co., London (1939).

[17] Charles B. Read, "Plantas Fosseis do Neo-Paleozóico do Paraná et Santa Catarina," *Brasil Div. Geol. e Miner. Mon. 12* (1941). 102 pp.
T. W. E. David and C. A. Sussmilch, "The Carboniferous and Permian Periods in Australia," *Rept. XVI Internat. Geol. Cong.*, Vol. 1 (1936), pp. 629–44.
Alex. L. duToit, "The Division of the Late Paleozoic Formations of Gondwanaland," *ibid.*, pp. 645–55.

[18] Emily Dix, "The Succession of Fossil Plants in the South Wales Coal Field," *Cong. Av. Etud. Strat. Carb., 2d Heerlen, 1935, Compt. Rend.*, t. 1 (1937), pp. 159–84.

[19] W. S. Bisat, "The Faunal Stratigraphy and Goniatite Phylogeny of the Carboniferous of Western Europe, with Notes on Connecting Links with North America," *16th Internat. Geol. Cong. (1933)*, Vol. 1 (1936), pp. 529–37.

gebirgian) between lower and upper Namurian.[20] An outstanding unconformity of the Carboniferous of the Moscow coal basin is shown by a nearly if not complete absence of Namurian equivalents.[21] Muller and Schenck[22] have called attention to classification in 1940 by Rauser-Cernoussova and others of the Carboniferous of the U.S.S.R. into Lower, Middle, and Upper series. That an important hiatus exists in eastern Europe comparable with the widespread Mississippian-Pennsylvanian unconformity in North America is indicated by this study which shows that the *Fusulinella* zone is separated from Viséan rocks by only 54 meter thickness of so-called "transition" beds. In contrast to this, shales, sandstones, and limestones between the equivalent Lampasas and lower Chester rocks in southeastern Oklahoma attain a thickness as great as 15,000 feet.

Widely differing classifications of the Carboniferous beds in Europe are illustrated in Table 1 of the guidebook for the Donetz coal basin excursion[23] as follows.

1. The 1927 and 1935 Heerlen conference favored two main divisions, *none* of the Namurian being placed in the Lower Carboniferous.

2. Zalessky and Tchirkova (1933) used two main divisions with a *restricted lower* Namurian included in the Lower Carboniferous.

3. Rotai, Zalessky, and others, in their "Geology of the U.S.S.R." (1937), divided the Carboniferous into three main divisions, *all* of the Namurian being included in the Lower Carboniferous.

The foregoing indicates that as yet there is no well established European classification of these rocks which geologists should seek to apply in other parts of the world.

Comparison of classification of Mississippian and Pennsylvanian rocks of North America with these three European classifications is shown herein by Chart I. This classification for North America is to be interpreted as a general plan as favored by a majority of the subcommittee. It is based on their interpre-

[20] Raymond C. Moore, "Late Paleozoic Crustal Movements of Europe and North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935) pp. 1253–1305.

W. J. Jongmans and W. Gothan, "Contribution to a Comparison between the Carboniferous Floras of the United States and of Western Europe," *Cong. Av. Etud. Strat. Carb., 2d Heerlen, 1935, Compt. Rend.*, t. 1 (1937), pp. 363–415.

Raymond C. Moore, "Comparison of the Carboniferous and Early Permian Rocks of North America and Europe," *ibid.*, 2 (1937), pp. 641–76.

A. K. Miller, "Studies of Carboniferous Ammonoids," *Jour. Paleon.*, Vol. 14, No. 4 (1940), p. 357.

R. C. Moore *et al.*, "Correlation of Pennsylvanian Formations of North America," *Bull. Geol. Soc. America*, Vol. 55 (1944), pp. 657–706.

[21] M. S. Shvetzov and V. S. Yablokov, "Excursion to the Moscow Coal Basin," *17th Internat. Geol. Cong.* (1937), Fig. 1 and pp. 16–17.

[22] Siemon Wm. Muller and Hubert G. Schenck, Review, "On Carboniferous Foraminifera of the Samara Bend," by D. Rauser-Cernoussova *et al.*, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 1943–49.

[23] P. Stepanov *et al.*, "The Southern Excursion, Donetz Coal Basin," *17th Internat. Geol. Cong.* (1937), Table I, pp. 20–21.

tation of geologic data and current usage, with due consideration to priority and utility.

A wide variety of opinion has been expressed by geologists of the 28 State geological surveys and others as to what should be done with the term Carboniferous. Many recommend that this name be discarded entirely whereas others maintain that it might be retained as a useful general term where differentiation into Mississippian and Pennsylvanian has not been made or is uncertain. If this procedure is followed, quotation marks appear appropriate only when the expression "Carboniferous *system*" is used.

Few, if any, have followed Nalivkin's[23a] proposed compromise of restricting the name Carboniferous to the Coal-measures (or Pennsylvanian) and using Mississippian for the next older system throughout the world. However, it is important to note that because of the pronounced differences and widespread hiatus between these systems, he pointed out the logic of dividing middle and upper Paleozoic rocks at the top of the Mississippian; the Devonian and Mississippian to be referred to as the age of fishes, the Pennsylvanian and Permian, the age of amphibians.

The early expression "Carboniferous order" might be restored as an inclusive term for the Mississippian and Pennsylvanian systems, the term "order" being used as a super-system term which is not provided in present classification codes for reference to two related geologic systems. Such non-comittal expressions as Carboniferous rocks and Carboniferous age (without quotation marks) may be useful and sufficient until the terminology becomes more uniform and better established.

## CONCLUSIONS

The foregoing considerations have led the subcommittee to the following conclusions.

1. Consistent and orderly treatment of geologic history requires that geologic time between the Devonian and Permian be divided into two independent geologic periods, the rocks related thereto being classified as two systems.

2. Priority and predominating usage commend world-wide application of the names Mississippian and Pennsylvanian to these periods and systems.

3. Division between Mississippian and Pennsylvanian at the Chester-Pottsville boundary is well established in the United States. World-wide use of this boundary is favored by occurrence of an equivalent major unconformity and paleontologic break in many places in Europe and elsewhere.

4. The Mississippian rocks of the upper Mississippi Valley and Pennsylvanian rocks of the near-by Mid-Continent region are particularly well qualified to serve as world standards of reference for the following reasons.

[23a] D. Nalivkin, "Major Divisions of the Paleozoic of the Union of Soviet Socialist Republics," *Rept. XVI Internat. Geol. Cong.*, Vol. 1 (1936), pp. 573–83.

a. The stratigraphic sequence is relatively complete, accessible, well exposed and suitable for differentiation.

b. Both marine and continental deposits are present, with fossiliferous marine rocks predominating.

c. Recurrent periods of deformation are well recorded.

d. Intensive studies of the area at the surface and in the subsurface, have amassed a great fund of geologic data on the basis of which correlations are becoming well established, and classification and usage more and more uniform. It is, of course, clearly understood that establishment of standard sections or of a section of reference is not to be attained by fiat but may come about only by actual use.

## PART II

## MAIN DIVISIONS OF MISSISSIPPIAN

### CLASSIFICATION

At the present time there is fairly complete agreement among geologists in the United States as to the main subdivisions of the Mississippian system. A detailed classification and correlation chart with discussion will be published in due time by the Mississippian subcommittee of the Committee on Stratigraphy of the National Research Council. For present purposes, reference is made to review and correlation chart of Mississippian rocks by Dott.[24]

The type and standard sections of the Mississippian system and series are in the upper Mississippi Valley region. Recent usage has favored classifying the Mississippian rocks as follows.

| | |
|---|---|
| Upper Mississippian | Chester series |
| Middle Mississippian | Meramec series<br>Osage series |
| Lower Mississippian | Kinderhook series |

In certain reports the Kinderhook and Osage groups have been classified as Lower Mississippian or as the Waverlyan "system" or series; and the Meramec and Chester as the Upper Mississippian or the Tennesseean. The name Valmeyer series has been used to include the Osage and Meramec groups. Some geologists prefer classifying the Kinderhook, Osage and Meramec groups as divisions of the Iowa series. The origin and use of these various names are discussed in the "Lexicon of Geologic Names of the United States."[25]

Certain problems regarding the placement of systemic and series boundaries remain unsettled, especially where thick clastics occupy positions at or near these boundaries. It is possible that some lower part of the Stanley, Tesnus, and Parkwood may be finally assigned to the Mississippian and some upper beds now in-

[24] Robt. H. Dott, "Regional Stratigraphy of Mid-Continent," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 1646–60.

[25] M. Grace Wilmarth, *U. S. Geol. Survey Bull. 898* (1939).

cluded in the Mauch Chunk may be assigned eventually to the Pennsylvanian. From limited microfaunal studies, Cooper[26] is inclined to believe that the upper 1,000 feet approximately of strata now called Mauch Chunk are of earliest Pennsylvanian age and that the underlying 2,000 feet are post-Kincaid (uppermost Chester formation of Illinois) but assignable to the Mississippian. Due to the short time interval indicated by minor faunal and floral advances, it appears likely that these rapidly deposited localized Mauch Chunk sediments may be included satisfactorily in the Pocahontas or in the Chester series, or both.

### STRATIGRAPHY, PALEONTOLOGY, AND CORRELATIONS

Detailed descriptions and faunal lists of Mississippian rocks have been published recently by Laudon and Bowsher,[27] Lee,[28] Stockdale,[29] and Weller and Sutton;[30] and numerous shorter papers have given detailed reviews of stratigraphy and structure.

On the basis of paleontological evidence it is generally agreed that the lower Namurian of Europe is approximately equivalent to the upper Chester of North America; the upper Namurian being correlative with lower and lower-middle Pottsville, that is, Pocahontas-Springer and lower Morrow. Placement of the division between the Mississippian and Pennsylvanian periods at the close of Chester time appears too well supported by usage in North America to attempt revision to a position equivalent to either the upper or lower Namurian boundary. Hope for reconciliation of diverse usage appears to lie in retention of the Chester-Pottsville boundary and its approximate equivalent within the Namurian of Europe for a systemic partition. That it is already being so used by some European geologists is shown in Chart I. It is recognized that in parts of Europe the Sudetan orogeny between the Viséan and Namurian stages is of such importance that geologists in Europe will doubtless wish to continue using this hiatus as a stage or series boundary closely comparable with the Meramec-Chester boundary in North America.[31]

### TECHNIQUE OF STRATIGRAPHIC NOMENCLATURE APPLIED TO MISSISSIPPIAN

In subdividing systems, some geologists favor using Upper, Middle and Lower

[26] Chalmer L. Cooper, personal communication, July 28, 1943.

[27] L. R. Laudon and A. L. Bowsher, "Mississippian Formations of Sacramento Mountains, New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 2107–60.

[28] Wallace Lee, "Subsurface Mississippian Rocks of Kansas," *Kansas Geol. Survey Bull. 33* (1940). 114 pp.

[29] Paris B. Stockdale, "Lower Mississippian Rocks of the East-Central Interior," *Geol. Soc. America Spec. Paper 22* (1939). 248 pp.

[30] J. Marvin Weller and A. H. Sutton, "Mississippian Border of Eastern Interior Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 765–858.

[31] A. K. Miller and W. M. Furnish, "Studies of Carboniferous Ammonoids," *Jour. Paleon.*, Vol. 14 (1940), pp. 356–77.

divisions, each with series rank. If this is applied to the Mississippian system, the Osage, and Meramec should be assigned the rank of groups or stages. In either case the four divisions are meant to serve as time-stratigraphic units, which in in their complete development include the entire Mississippian system. Correlative rocks outside the type areas may be referred to as Kinderhookian, Osagian, Meramekian or Chesterian, although this subcommittee is not unanimous in the opinion that the suffix "ian" is an essential or a desirable elaboration of a standard series or stage name.

Published discussions[32] show wide differences of opinion regarding the use of the terms series and stage and the need of suffixes such as "ic" and "ian." In no part of the world do geologists hold rigidly to division of all systems into Upper, Middle, and Lower series. More flexibility and directness are achieved by dividing systems according to their inherent characteristics into two or more series bearing appropriate geographically derived names, applying the adjectives lower, middle, and upper to the systemic name with more or less definite meaning but as general terms. Use of such expressions as "of Chester age" or "during Chester time," for example, has more certain meaning and eliminates the need of suffixes. Thus, as indicated by the report of a committee representing four American geological organizations,[33] simplification (and perhaps other reasons) has in the past led toward disuse in the United States of the term "stage" (except as a time term for major subdivisions of the Pleistocene epoch) and of suffixes appended to series and epoch names, seemingly without sacrifice of precision or clarity. Signs of reversion of these trends are now apparent. In many areas groups and formations of Mississippian and Pennsylvanian rocks can be and are used with strict time-stratigraphic limitations.

### CONCLUSIONS REGARDING MISSISSIPPIAN

1. Objective facts, usage, and priority support classification of the Mississippian rocks as a system.

2. The type and standard sections of the Mississippian system are located in the Mississippi River Valley.

3. The Mississippian standard section is logically divided into the Kinderhook, Osage, Meramec, and Chester series; the Kinderhook being referred to as the Lower, Osage and Meramec as the Middle, and the Chester as the Upper Mississippian divisions.

[32] G. H. Ashley *et al.*, "Classification and Nomenclature of Rock Units," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17 (1933), pp. 843–63. Reprinted, Vol. 23 (1939), pp. 1068–88.
C. W. Tomlinson, *op. cit.*, pp. 2038–46.
H. G. Schenck *et al.*, "Stratigraphic Nomenclature," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 2195–2211.
H. G. Schenck and Siemon Muller, "Stratigraphic Terminology," *Bull. Geol. Soc. America*, Vol. 52 (1941), pp. 1419–26.

[33] G. H. Ashley *et al.*, *op. cit.*

## Part III

## Main Divisions of Pennsylvanian

### CLASSIFICATION

As heretofore shown, geologists of the United States are in nearly complete agreement regarding the systemic rank and the position of limiting boundaries of the Pennsylvanian rocks. Some differences of opinion and usage remain as to certain details of the boundaries, names and correlation of the principal subdivisions. Undoubtedly, the stratigraphic record reveals a far more complex geologic history during Pennsylvanian time than during most geologic periods. The composite section of Pennsylvanian rocks in Oklahoma has a total thickness in excess of 36,000 feet, reveals at least six distinct episodes of diastrophism, and includes records of numerous invasions and retreats of the sea.

In North America during Pennsylvanian time several extensive geosynclines were formed more or less progressively, independently, and apparently with less lack of synchronism than might be suspected. An endless variety of conditions developed successively within these basins, controlling the environment and character of deposit horizontally and vertically. Problems of classification and correlation arise not only as a result of differences of organic evolution, ecology and character of sediments, but also from the limited stratigraphic record now available for analysis. Added difficulties have arisen from fortuitous causes, such as time and place of pioneer geological investigations which required prompt differentiation and naming of rock units for each new region.

Provincial names for the main stratigraphic subdivisions of large more or less isolated regions connote certain individuality of stratigraphy as well as geographic location. Such names, ingrained and developed by many years of usage, can not be readily displaced. Because of the distinctive character of the rocks of each of these large areas, many of these names may continue to serve advantageously. However, the usefulness of such subdivisions, bearing provincial names, can be very materially increased and relationships with other regions more definitely and readily established if the partition of the rock column is rearranged on a time-stratigraphic basis, thereby replacing classification by *groups*, based on prevailing lithology as observed in preliminary investigation, with classification by *series* based on pronounced faunal, structural and lithologic changes. At best, many difficulties are encountered in determining regional and interbasin equivalences, particularly in areas of limited outcropping, incomplete rock sequences or changing facies. Thus the establishment of standard sections and sections of reference with time-stratigraphic divisions appears highly advantageous, especially to petroleum geologists who must decipher from limited evidence the geologic features and relationships over large areas.

Initial recognition of systems and series is most likely to occur in areas where the stratigraphic column is incomplete and hiatuses are pronounced. As measured in their type localities the Pottsville, Allegheny, Conemaugh and Monongahela

subdivisions have a total thickness of approximately 3,000 feet or about one-third the composite maximum thickness of the Pennsylvanian system in the Appalachian region, one-twelfth that in Oklahoma.

Expanding studies in the Appalachian region long ago led to the custom of dividing the Pottsville into lower, middle, and upper divisions. David White reported that equivalent paleobotanic divisions are recognizable "stage by stage" in many other areas, including some as far away as the basin of Heraclea in Asia Minor.[34] These divisions evidently have time-stratigraphic significance, and may properly be classified as three geologic series because of their individuality and extensive development in geosynclinal areas where each division attains a thickness ranging from 3,000 to 10,000 feet.

The post-Pottsville Pennsylvanian beds of western Pennsylvania have also been divided into three divisions, with boundaries selected largely on the basis of lithologic character and abundance or lack of workable coal. Moderate revision of certain boundaries would qualify these lithologic groups as time-rock units (series), having increased usefulness in interregional studies and more accuracy in local interpretations. Needed readjustments of boundaries for this purpose are shown in the "progress report" of the Pennsylvanian subcommittee of the National Research Council which gives an excellent and comprehensive summary of stratigraphic and paleontologic data on the Pennsylvanian rocks of North America.[35] Collaboration of many specialists was obtained in preparing this report and the correlation chart (No. 6 of the National Research Council series) which lists the important members, formations, and groups for 82 areas across North America.In this report the Pennsylvanian rocks of the Appalachian region are divided into the Lee, Kanawha, Allegheny, Conemaugh, and Monongahela series; and those of the Mid-Continent region into the Morrow, Lampasas, Des Moines, Missouri, and Virgil series. Floral and faunal zones are designated and correlations with European equivalents indicated. A diagrammatic cross section from West Virginia to Oklahoma shows the position of nine faunal subzones as well as the prevailing lithologic character and local names of many of the important stratigraphic units.

Differences of classification between the reports of the subcommittees of the National Research Council and the Association are relatively few in number. Discussion of these differences should serve to focus attention on certain unsettled problems and thereby hasten progress in their solution. The classification adopted for the present report differs from that of the National Research Council subcommittee chiefly as to the points here listed.

1. The time-honored custom is followed herein of dividing the Pottsville into three divisions. These are most commonly referred to as the Pocohontas, New River, and Kanawha in the Applachian region and Springer, Morrow, and Lam-

[34] David White, "The Upper Paleozoic Floras, Their Succession and Range," *Outlines of Geologic History*, Univ. Chicago Press (1912), p. 147.

[35] R. C. Moore *et al.*, "Correlation of Pennsylvanian Formations of North America," *Bull. Geol. Soc. America*, Vol. 55 (1944), pp. 657–706.

## CHART II

### CLASSIFICATION OF PENNSYLVANIAN SYSTEM OF NORTH AMERICA

| | Type Section of System | Co-Standard Sections | | Important Reference Section | Diastrophism |
|---|---|---|---|---|---|
| | State of Pennsylvania and Vicinity | Appalachian Region | Mid-Continent Region | Mid-Continent Region | Mid-Continent Region |
| | Series<br>Type Localities | Series<br>Type Localities | Series<br>Type Localities | Series<br>Type Localities | |
| Upper | MONONGAHELA<br>Monongahela River Valley<br>Western Pennsylvania | Waynesboro coal<br>MONONGAHELA<br>Monongahela River Valley<br>SW. Pennsylvania<br>N. West Virginia<br>Morgantown ss. | Brownville ls.<br>VIRGIL<br>Verdigris River Valley<br>Eastern Kansas<br>Stranger fm. | | Marathon<br>Regional elevation of Ouachitas |
| Upper | CONEMAUGH<br>Conemaugh River Valley<br>Western Pennsylvania | CONEMAUGH<br>Conemaugh River Valley<br>SW. Pennsylvania<br>Mahoning ss. | MISSOURI<br>Missouri River Valley<br>NW. Missouri<br>NE. Kansas<br>Bourbon group | HOXBAR<br>3000 feet<br>South Ardmore basin<br>Union Dairy ls. | Arbuckle-Wichita |
| Middle | ALLEGHENY<br>Allegheny River Valley<br>Western Pennsylvania | ALLEGHENY<br>Allegheny River Valley<br>Western Pennsylvania<br>Kittanning ss. | DES MOINES<br>East-central Oklahoma<br>Up. Boggy sh. | Confederate ls.<br>DEESE<br>7000 feet<br>South Ardmore basin | Widespread unconformity<br>Hunton-Ozark<br>Wichita-Ouachita front |
| Middle | E | Homewood ss. | Parks group | Pumpkin Ck. beds | Marathon-Concho |
| Middle | UPPER POTTSVILLE<br>Eastern Pennsylvania<br>D | KANAWHA<br>Kanawha River Valley<br>Western West Virginia<br>L. Connoquenessing ss. | Smithwick group<br>LAMPASAS<br>Colorado-Llano River<br>Valleys, Cent. Texas<br>Big Saline group | Frensley ls.<br>UPPER DORNICK HILLS<br>2500 feet<br>South Ardmore basin<br>Bostwick cong. | Hunton-Central Kansas<br>Widespread unconformity<br>Wichita-Ouachita |
| Lower | MIDDLE POTTSVILLE<br>C<br>Eastern Pennsylvania<br>B | NEW RIVER<br>(Sewell)<br>New River Valley<br>Southern West Virginia<br>L. Raleigh ss. | MORROW<br>Northwestern Arkansas<br>Up. Hale fm. | Ot erville ls.<br>LOWER DORNICK HILLS<br>2500 feet<br>Ardmore basin<br>Primrose ss. | Ouachita-Nemaha (?)<br>Wichita-Criner Hills |
| Lower | LOWER POTTSVILLE<br>A Eastern Pennsylvania | POCAHONTAS<br>(Lee)<br>Southern West Virginia<br>Squire Jim Coal | SPRINGER<br>Ardmore basin<br>Southern Oklahoma<br>Goddard shale | SPRINGER<br>4000 feet<br>Ardmore basin<br>Goddard shale | Ozark and central continental axes<br>Llanoria |

CHART II.—Classification and correlation of the type Pennsylvanian section of eastern and western Pennsylvania with the more complete co-standard sections of the Appalachian and Mid-Continent regions. Comparison is extended to the especially complete Ardmore basin section as an important section of reference. Approximate time of the major diastrophic episodes revealed by rocks of the Mid-Continent region are also shown. Broken lines signify alternative location of boundaries.

pasas in the Mid-Continent region. (Pronunciation: Ka-na′-wha, Lam-pas′-as.)

2. The widely recognizable boundaries between the Morrow-Lampasas and Des Moines-Missouri series are emphasized as the logical partitions between Lower, Middle and Upper Pennsylvanian. Fossils of the Lower Pennsylvanian show affinities with the Mississippian and those of the Upper with the Permian. The other boundaries, between Springer-Morrow, Lampasas-Des Moines, and Missouri-Virgil series, seem to be somewhat less pronounced paleontologically.

3. The question of restricting the upper boundary of the Kanawha and Lampasas series to the top of the *Fusulinella* (pre-*Fusulina*) zone, or using some higher boundary, was reviewed in hope of accelerating agreement on this problem of both the Appalachian and Mid-Continent regions. Opposing factors seem to be nearly of equal weight. This subcommittee has not had opportunity for adequate discussion and adoption of a recommendation. Presumably, settlement of this question should not be based exclusively on the physical conditions, usage, and priority of the type Pennsylvanian section. General agreement will require consideration of similar data from other major geologic provinces.

4. The inherent fitness of the Pennsylvanian rocks of the Mid-Continent region to serve as a standard section of the Pennsylvanian system is stressed. Likewise, the sections of the Ardmore basin and near-by areas are recognized as particularly suited to fulfill the need of a relatively complete section of reference. The Pennsylvanian of the Mid-Continent region offers definite advantages over other well known sections in North America because of greater content of fossiliferous marine deposits, more distinct record of several episodes of diastrophic activity, and more complete geologic section. This region is centrally located and will continue to receive intensive study of the petrology and macro-fossils and microfossils, both in the well exposed surface sections and in the subsurface of the very large oil-producing area extending from Nebraska to Texas. (The cross section added to Chart No. 6 of the National Research Council report was not designed to show the complete Mid-Continent section.)

Chart II shows a *generalized* plan of classification of the Pennsylvanian rocks of North America. Standard sections of the Appalachian and Mid-Continent regions are divided into six divisions and compared with the type section of the system in Pennsylvania. The Ardmore basin section, supplemented by the Virgil series of eastern Kansas, is suggested as an excellent section of reference. This proposed use of the Ardmore basin Pennsylvanian rocks as a section of reference for the lower five series appears highly advantageous because of the presence of a relatively complete, continuous section some 20,000 feet thick in an area a few miles wide. Furthermore, the Ardmore basin section consists in large measure of fossiliferous marine deposits, well exposed and clearly recording several distinct intervals of diastrophic activity. The section of Springer to Hoxbar rocks located a few miles south of Ardmore in the area now set aside as the Lake Murray State Park is selected as the site of this section of reference. (Year-round cabin and park

service are available.) Intensive geological study of the exposed and buried Pennsylvanian rocks of this region is certain to continue.

### CONCLUSION REGARDING PENNSYLVANIAN

1. Pennsylvanian rocks are more appropriately classified as a system rather than a sub-system or series of the Carboniferous system.

2. The type section in Pennsylvania, supplemented by co-standard sections of the Appalachian and Mid-Continent regions and an especially complete section of reference in the Ardmore basin, presents an unusually complete record of the faunal, structural, and depositional developments which took place during the Pennsylvanian period, and may well serve as a world standard for this exceptionally important chapter of geologic time.

3. The Pennsylvanian system may logically be subdivided into six divisions: the Pocahontas, New River, Kanawha, Allegheny, Conemaugh, and Monongahela of the standard Appalachian section, and the Springer, Morrow, Lampasas, Des Moines, Missouri, and Virgil series of the standard Mid-Continent section. Faunal and structural criteria may be used to establish equivalent series in other geologic provinces, thereby gaining the advantage of time-stratigraphic divisions useful for interregional correlations.

4. Faunal and structural relationships favor grouping of the lower two, middle two, and upper two series in referring to Lower, Middle, and Upper divisions of the Pennsylvanian system.

## Discussion: Main Divisions of Pennsylvanian System

M. G. CHENEY

### INTRODUCTION

The Association subcommittee on classification of Carboniferous rocks of North America has devoted considerable attention and correspondence to the difficult problems of classification and correlation of major divisions of the Pennsylvanian system. Conditions during recent years have prevented the holding of conferences which might have led to the adoption of subcommittee recommendations. The following discussion reviews some of the literature and presents certain views now held by one or more members of the subcommittee. The chairman of the subcommittee assumes the responsibility for authorship of this discussion and acknowledges much help from fellow members and others listed in the subcommittee report. Footnote citations are numbered to follow those in the preceding report, which concluded the work of the subcommittee. It is hoped that this added discussion will stimulate interest in the problems which remain unsettled; also, that it will contribute something toward the solution thereof.

### LOWER POTTSVILLE: POCAHONTAS SERIES—SPRINGER SERIES

For the past 40 years the lower Pottsville division has been called the Pocahontas formation or group over a large part of the Appalachian region, also called

Lee *et cetera* in other parts. For 22 years the name Springer has been applied to the approximate equivalent in the Mid-Continent. This lowest Pennsylvanian epoch is characterized by *Neuropteris pocahontas* and has recently been designated the Pottsville A zone by Ashley.[36] A distinctive microfaunal assemblage including *Haplophragmoides* sp.[37] is recognized in the Springer series of the Ardmore basin and Ouachita region.[38] Revision of Goldston's[39] Springer "member" to include all Pennsylvanian beds below the base of the Primrose sandstone, and for elevating the Springer division to the rank of series will be recommended in a forthcoming paper by Robert H. Dott. As revised, the Springer series is about 4,000 feet thick in its type area north of Ardmore. About 2,000 feet of dark shales below the Rod Club sandstone are now included in the Springer series. These lower Springer shales, heretofore called the "Pennsylvanian Caney," have been given the name of Goddard shale formation.[40]

The regional correlatives of this lowest Pennsylvanian series are shown in Chart No. 6 of the National Research Council series already referred to.[41] This division should be useful for inter-continental correlations in that it is closely equivalent to the upper Namurian *Pecopteris aspera* zone of the South Wales coal fields, above a marked floral break recognized by Dix and others.[42]

The name Springer is used in preference to Harlton's[43] Pushmataha for this lowest Pennsylvanian series partly because of priority and usage, but chiefly to avoid placing the type locality of this series in a less accessible area where stratigraphic relationships are uncertain due to exceedingly complex overthrust faulting and folding.

According to later work by Harlton and others,[44] his very useful correlation chart[45] and earlier correlations between the Ardmore and Ouachita areas require certain revisions, as follows: "the top of Morrow is base of Bostwick, top of

[36] R. C. Moore *et al.*, *op. cit.* (1944), p. 682.

[37] H. H. Bradfield, "Pennsylvanian Ostracoda of the Ardmore Basin, Oklahoma," *Bull. Amer. Paleon.*, Vol. 22, No. 73 (1935), pp. 10–11.

[38] Bruce H. Harlton, "Stratigraphy of the Bendian of the Oklahoma Salient of the Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 870–89.

[39] W. L. Goldston, Jr., "Differentiation and Structure of the Glenn Formation," *ibid.*, Vol. 6 (1922), pp. 5–23.

[40] Jerome M. Westheimer (personal communication) has proposed the name of Goddard shale formation to replace the term "Pennsylvanian Caney." The type locality is along Oil Creek, Secs. 19 and 20, T. 3 S., R. 4 E., on the Goddard ranch about 7 miles east of Gene Autry (Berwin on older maps), Oklahoma. The Goddard shale formation consists of uniform dark shales with some thin concretionary layers between the top of the Mississippian rocks (commonly the Caney shale of Meramec age according to Ulrich [*Oklahoma Geol. Survey Bull. 45* (1927), p. 25]) and the base of the Rod Club sandstone. In its type area the Goddard shale attains a thickness of at least 2,000 feet.

[41] R. C. Moore *et al.*, *op. cit.* (1944).

[42] E. Dix, *op. cit.*, p. 161.

[43] Bruce H. Harlton, *op. cit.* (1938).

[44] Personal communication, June 29, 1943: Bruce H. Harlton, R. V. Hollingsworth, and Jerome M. Westheimer.

[45] Bruce H. Harlton, *op. cit.*, p. 854.

Wapanucka and top of Bloyd"; and the upper part of the Hale sandstone of northwestern Arkansas is to be correlated with the Primrose sandstone (basal Morrow), the lower Hale with the upper Springer series. The Springer series in the Ouachita basin of southeastern Oklahoma and west-central Arkansas attains a thickness estimated as great as 15,000 feet, on the assumption that the clastic Hot Springs sandstone, Stanley shale, and Jackfork sandstone are all of post-Chester age, and properly assigned to the Pennsylvanian.[46] White[47] quotes other paleontologists as agreeing with him in the correlation of these beds with lower Pottsville.

The vast amount of clastic material which makes up the rocks of Springer age in the Ardmore basin and Ouachita trough evidently came, in large part, from a broad borderland region on the southeast, called Llanoria by Miser,[48] and to a lesser degree from interior positive areas of the present North American continent, including such features as the Ozark dome, Hunton and Nemaha axes, and Central Kansas uplift. Formation of the deep Ouachita trough or tectogene[49] followed relatively stabilized conditions during which widespread marine deposits were formed elsewhere in Chester time and in turn preceded conditions under which broad epeiric seas left their record of fossiliferous calcareous deposits of Morrow age. The Criner Hills orogeny probably began near the close of Springer time and became sufficiently pronounced by medial Morrow time that extensive conglomerates composed of pre-Springer rocks from this area were being deposited in the Ardmore basin.[50] This is doubtless a part of an extensive orogeny which van der Gracht[51] called the Wichita orogeny. Likewise, in the Ouachita region the Stapp conglomerate and other features led Harlton to conclude that "The opening stage of the Morrow deserves high rank in the classification of orogenic movements."[52] The Tesnus trough of southwestern Texas and Appalachian trough of the eastern United States appear to have had a much similar diastrophic and depositional history before, during, and at the close of early Pottsville time.

### MIDDLE POTTSVILLE: NEW RIVER SERIES–MORROW SERIES

The middle Pottsville has generally been referred to as the New River formation or group in much of the Appalachian region. It includes the *Mariopteris potts-*

[46] Hugh D. Miser, "Carboniferous Rocks of Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18 (1934), pp. 971–1099.

[47] David White, "Age of Jackfork and Stanley formations of Ouachita Geosyncline, Arkansas and Oklahoma, as Indicated by Plants," *ibid.*, Vol. 18 (1934), pp. 1010–17.

[48] H. D. Miser, "Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas," *Amer. Jour. Sci.*, 5th *Ser.*, Vol. 2 (1921), pp. 61–89.

[49] H. H. Hess, "Gravity Anomalies and Island Arc Structure with Particular Reference to the West Indies," *Proc. Amer. Philos. Soc.*, Vol. 79 (1938), pp. 71–96.
O. D. von Engeln, *Geomorphology*, The Macmillan Company, New York (1942), pp. 44–45.

[50] C. W. Tomlinson, "The Pennsylvanian System in the Ardmore Basin," *Oklahoma Geol. Survey Bull. 46* (1929), Pl. XVII, sec. AA, and pp. 20–24.

[51] W. A. J. M. van Waterschoot van der Gracht, "Permo-Carboniferous Orogeny in South-Central United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 9 (1931), Table 1, p. 1002.

[52] Bruce H. Harlton, *op. cit.* (1938), p. 861.

*villea* zone (Pottsville B of Ashley and *Neuropteris schlehani* of Europe) in the lower part, *Mariopteris pygmaea* zone (Ashley's Pottsville C and *Neuropteris heterophylla* of Europe) in the upper part. Some restriction of lower and upper boundaries seems necessary if this division is to serve as a series rather than a group. According to Chart No. 6 of the National Research Council report[53] this division should preferably extend from the base of the Lower Raleigh sandstone to the base of the Upper Nuttall sandstone of the southern West Virginia section. The correlative Sharon conglomerate, Olean conglomerate, Rockcastle conglomerate, Lower Caseyville conglomerate, and lower conglomerate of the Lookout formation seem to mark the natural lower boundary of this series in other parts of the Appalachian region. Likewise, the base of the Lower Connoquenessing sandstone, Corbin conglomerate, Upper Caseyville conglomerate, and the base of Upper Nuttall sandstone are interpreted as marking an unconformity that may serve well as the boundary between the New River and succeeding Kanawha series. In some reports this middle Pottsville division has been called the Sewell group.

A majority of the Association subcommittee favor restriction of the term Morrow series of the Mid-Continent section to rocks of middle Pottsville age. These rocks attain a thickness of at least 2,500 feet in the Ardmore basin section of reference. In this section the lower boundary is placed at the base of the Primrose sand and the upper boundary at the base of the Bostwick conglomerate. The intervening beds are notably distinct from the Springer series in lithologic character, flora, and microfauna.[54] The Morrow beds are more calcareous and fossiliferous, and include coarse conglomerates. This increase in calcareous and coarse clastic content is perhaps partly explained by initial uplift and consequent erosional attack upon earlier Paleozoic limestones in the Criner Hills and larger upfolded areas of the Wichita orogeny to the south and west. Also, Harlton[55-56] has concluded that major diastrophic changes were taking place near the close of Springer time in the Ouachita region, where fault blocks and sharp folding seemingly produced a rugged topography, subject to wave undercutting and land slips. Subsequent disturbances near the close of Morrow time are also postulated by this author from the character of the Round Prairie (Johns Valley shale) formation which shows much reworking of material derived from the Stapp conglomerate. Still later folding and thrusting have further complicated the geology of this area. Due to their great size, the boulders of this region, like those in the Haymond beds of Lampasas age in southwestern Texas, have been the subject of much discussion.[57]

[53] R. C. Moore *et al.*, *op. cit.* (1944).

[54] H. H. Bradfield, *op. cit.*
Bruce H. Harlton, *op. cit.* (1938).

[55–56] Bruce H. Harlton, *op. cit.* (1938), pp. 893–900 and Fig. 5.

[57] H. D. Miser, "Carboniferous Rocks of the Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18 (1934), pp. 971–1099.
Philip B. King, "Geology of the Marathon Region, Texas," *U. S. Survey Prof. Paper 187* (1937), pp. 66–68, Pl. 10.

During this Early Pennsylvanian time, periodic movements doubtless accentuated the positive elements of the interior continental area. These features include the Hunton and Ozark arches, Nemaha axis, Central Kansas uplift, Ancestral Rockies, and Concho arch.

Over large parts of North America the lower and middle Pottsville beds are absent but to what extent this is due to lack of deposition or to truncation as a result of diastrophism contemporaneous with the disturbances noted in Oklahoma near the close of Springer, Morrow, and Lampasas time remains uncertain in many areas. Evidence of unconformity between Morrow and Atoka (lower Lampasas) is very widespread and pronounced in eastern Oklahoma. In the Appalachian region, there is much additional paleontologic and structural evidence favoring establishment of the middle Pottsville as a separate series, quite as distinct and important as some of the well recognized later series of this system.

### ALLEGHENY: ALLEGHENY SERIES–DES MOINES SERIES
### UPPER POTTSVILLE: KANAWHA SERIES–LAMPASAS SERIES

These two divisions are grouped as of Medial Pennsylvanian age because of the widespread unconformities and pronounced paleontologic changes below and above their combined section. Mississippian affinities largely disappeared by the end of Morrow time; Permian relationships are much less evident than in the Later Pennsylvanian.

The Kanawha or Lampasas series of some areas include both the Westphalian B and C stages of the European classification but in other areas they have been limited to Westphalian B or the zones of *Cannophyllites* and *Neuropteris tenuifolia* of the Appalachian area. These zones are correlated with the European *Lonchopteris* and *Neuropteris tenuifolia* floral zones; E and F of Dix, in South Wales and England. The succeeding Westphalian C stage (zone G of Dix) is characterized by *Neuropteris rarinervis*, both in Europe and North America. It is closely equivalent to the Clarion group of the Appalachian area. Most or all beds of Clarion age have been assigned to the upper Pottsville in reports of the West Virginia, Kentucky, and Illinois State Geological Surveys for several decades. Recently the Pennsylvania Survey has re-endorsed this classification. As quoted by Moore,[58] G. H. Ashley (State geologist of Pennsylvania) now advocates placing both the Clarion and Mercer groups in an uppermost Pottsville E division, having as its base the pronounced floral break just below the Mercer group and extending up to base of Kittanning beds.[59] Moore's Chart No. 6 follows the custom of the Ohio Survey and until recently of the Pennsylvania Survey of placing the Pottsville-Allegheny boundary at or near the top of the Mercer group; however, in Moore's chart the boundary is drawn at the base rather than the top of the Homewood sandstone.

[58] R. C. Moore, *op. cit.* (1944), pp. 681–82.

[59] G. H. Ashley, "The Allegheny-Pottsville Boundary," *ms.* for the *25th Anniversary Volume, Topographic and Geologic Survey of Pennsylvania* (1944).

In western Pennsylvania and eastern Ohio the differently assigned upper Kanawha or basal Allegheny section includes such important members as the Homewood sandstone, Brookville coal, Putnam Hill limestone, Zaleski flint (equivalent to the Kanawha flint of West Virginia), Clarion sandstone, Clarion coal, and Vanport limestone. According to Ashley, the overlying Lower Kittanning coal is the lowest important workable coal of the Allegheny River section of western Pennsylvania; therefore, by original definition, it is properly placed at the base of the Allegheny series.[60] The Allegheny division was established about 36 years prior to the Pottsville. By definition and continued usage, type Pottsville beds extend up to the Buck Mt. coal (Kittanning) in eastern Pennsylvania.

### POTTSVILLE-ALLEGHENY BOUNDARY PROBLEM

Recent shift toward including the Clarion group in the upper Pottsville-Kanawha series of the type Pennsylvanian section is supported by paleontologic and other evidence observed in both the Appalachian and the Mid-Continent sections.

Read[61] states:

1. that the Clarion flora (which he formerly called "basal Allegheny" due to prevailing classification of the type section in Pennsylvania) is very similar if not identical with the upper Kanawha flora of West Virginia which has long been classified as upper Pottsville;
2. that the Clarion flora is more related to the Pottsville than to the Allegheny flora of Pennsylvania;
3. that the Kittanning flora marks the beginning of a new floral type (Allegheny);
4. that for these and other reasons he favors including the Clarion group in the Kanawha or upper Pottsville series.

It is of much interest to note in Ashley's recent cross section and manuscript that the Kittanning beds of the northern Appalachian region overlap various older members of the Clarion group and Homewood sandstone. Evidence from areas of more continuous deposition indicates that the hiatus between the Kittanning and Clarion beds in Pennsylvania may represent a considerable time interval.

Wanless has shown that the Clarion group with thickness of only 80 feet in western Pennsylvania and eastern Ohio is correlative with the upper Kanawha beds about 550 feet thick in West Virginia and eastern Kentucky.[62] He divides the entire Kanawha series into four sections (his Plates 4, 5, 6, and 7) bounded by important coal members. Kanawha beds increase from a total thickness of about 300 feet in eastern Ohio to nearly 4,000 feet in the West Virginia and Kentucky region. The lower Kanawha beds of Ohio contain early *Fusulinella*[63] as found in the Atoka of Oklahoma and Big Saline beds of Texas.

[60] H. D. Rogers, *Pennsylvania Geol. Survey 4th Ann. Rept.* (1840), p. 177.

[61] Chas. B. Read, personal communication, October, 1944.

[62] Harold R. Wanless, "Pennsylvanian Correlations in the Eastern Interior and Appalachian Coal Fields," *Geol. Soc. America Spec. Paper 17* (1939), Pl. 4.

[63] M. L. Thompson, "Pennsylvanian Fusulinids from Ohio," *Jour. Paleon.*, Vol. 10 (1936), pp. 673–83.

Hendricks[64] considers that beds as high as middle Boggy of the McAlester district, Oklahoma, should be classified as of upper Pottsville age on the basis of correlation with the Appalachian section and general relationships as judged by faunal and physical evidence of both regions.

Prior to 1940 the beds herein classified as Lampasas and Des Moines were included in a single Des Moines series in most or all publications on the geology of the Mid-Continent region although equivalent beds in the type Pennsylvanian section had long been separated into two divisions, the upper Pottsville and Allegheny. Lowman and Ware, in an unpublished manuscript, written in 1935, advocated revision by elevating the Atoka formation to a series.[65] Prior to that time Lowman had prepared a review[66] on structure and stratigraphy in which he divided the Des Moines series as follows.

| | |
|---|---|
| Marmaton: | Fort Scott limestone |
| Upper Cherokee: Calvin sandstone | Thurman sandstone |
| Middle Cherokee: Boggy formation | Lower Savanna sandstone |
| Lower Cherokee: McAlester shale | Atoka formation |

In this review Lowman asserted that the upper Cherokee and Marmaton are closely related and that

Major changes in the regional structure of the Mid-continent area seem to have been initiated between the middle and upper Cherokee as evidenced by the following data:

1, There is a broad regional unconformity at the base of the upper Cherokee. 2, Comparatively coarse sediments in the Chelsea-Thurman sandstone grade rapidly into finer sediments in the underground to the west indicating that the present line along which these sediments crop out is near their original shore line. 3, The area of maximum sedimentation in the upper Cherokee shifts many miles northwest of axis of the middle and lower Cherokee basins. 4, The line of strike changes with the advent of the Thurman. 5, The folds on the "Brown lime" (upper Savanna) in the Seminole area show that the folding during middle Cherokee time was in phase with lower Cherokee. On the other hand the structural expression of the "Senora lime" (upper Cherokee) is disconformable with the middle and lower Cherokee. 6, The southwestern extension of the Ozark Mountains into Oklahoma appears to have been elevated in upper Cherokee time. 7, Continued uplift of many and possibly all major local uplifts seem to have persisted with diminishing intensity through upper Cherokee time and on through Marmaton, Kansas City, Lansing, and Douglas time and many of the structures are well expressed in surface strata as young as Permian. However, the regional structures like the Henryetta flexure and the Central Oklahoma arch appear to have ceased moving with the end of the middle Cherokee time and all local folds are buried by upper Cherokee sediments.

The Hunton arch (proper) with attendant features such as the Henryetta flexure, the Seminole uplift, the Paul's Valley arch, and the Central Oklahoma arch and almost all important local "structures" had received their essential form by the end of the Middle Cherokee time and were only modified by later events.

Lowman's conclusions are well supported by cross sections with correlation

[64] Thomas A. Hendricks, personal communication, December, 1943.

[65] Shepard W. Lowman and John M. Ware, "Atoka Series," *ms.* (1935).

[66] Shepard W. Lowman, "Cherokee Structural History in Oklahoma," *Tulsa Geol. Soc. Digest* (1933), pp. 31–34.

tables such as the one prepared by him dated December 5, 1931, T. 5 N., Rs. 2–10 E., Oklahoma, shown in Figure 1.

Several possibilities must be considered in searching for the most logical boundary between upper Pottsville and Allegheny equivalents in the thick Oklahoma section. Each of the following possible choices merits consideration.

1. *Base of Thurman sandstone.*—This prominent sandstone and conglomerate truncates upper Boggy beds and has different direction of dip and trend of folding than older beds.[67]

2. *Unconformity between lower and upper Boggy.*—Plants of the upper Boggy are typically Alleghenyan, those below are mostly of Clarion age or "basal Allegheny" of earlier reports.[68] The brachiopods *Mesolobus striatus*, *Spirifer opimus*, and *Marginifera missouriensis*, reported from lower Boggy, are species characterizing Pottsville beds in Illinois and Ohio, and Lampasas of the Mid-Continent.[69]

Fusulinids of lower Boggy and upper Savanna, upper Tradewater and Clarion beds include *Fusulina leei* Skinner (*Fusulinella serotina* Thompson) and *F. pumila* which are about equally fusulinelloid and fusulinoid in shell structure.[70] It should be noted, however, that *Fusulina novamexicana*, a completely fusulinoid form occurs at least as low as the Spaniard limestone of the upper Savanna formation. Species rather than genera of the family of *Fusulinidae* must be used in separating Kanawha from Allegheny or Lampasas from Des Moines series if Clarion and equivalent beds are assigned to the upper Pottsville.

Pelecypods likewise record close relationship of Hartshorne-lower Boggy beds of Oklahoma with the Tradewater of Illinois as well as paleontologic differentiation of these beds from upper Cherokee and Marmaton.[71]

Red shales and very irregularly bedded sandstones in the lower part of the upper Boggy as noted in the Lake McAlester district[72] may be interpreted as

[67] George D. Morgan, "Geology of the Stonewall Quadrangle, Oklahoma," *Bur. Geol. Bull. 2* (1924), pp. 84, 145–50.

[68] T. A. Hendricks and C. B. Read, "Correlation of Pennsylvanian Strata in Arkansas and Oklahoma Coal Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18 (1934), p. 1056.

[69] Charles W. Wilson and Norman D. Newell, "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma." *Oklahoma Geol. Survey Bull. 57* (1937), pp. 51–56, Pt. III.

Carl O. Dunbar and G. E. Condra, "Brachiopods of the Pennsylvanian System in Nebraska," *Nebraska Geol. Survey Bull. 5*, 2d Ser. (1932), p. 23.

R. C. Moore *et al.*, *op. cit.* (1944), p. 675.

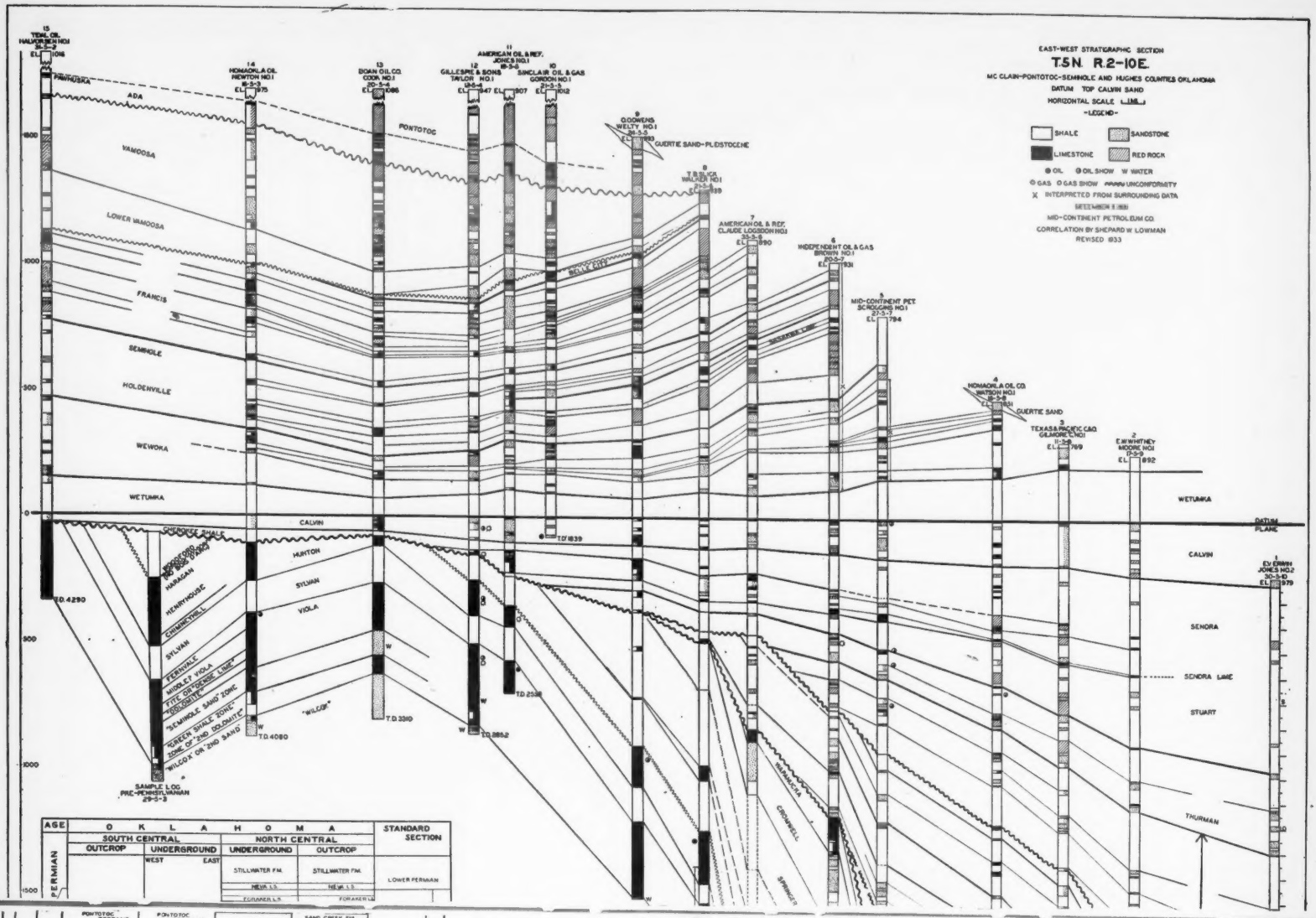
[70] Carl O. Dunbar, Lloyd G. Henbest, and J. Marvin Weller, "Pennsylvanian Fusulinids of Illinois," *Illinois Geol. Survey Bull. 67* (1942).

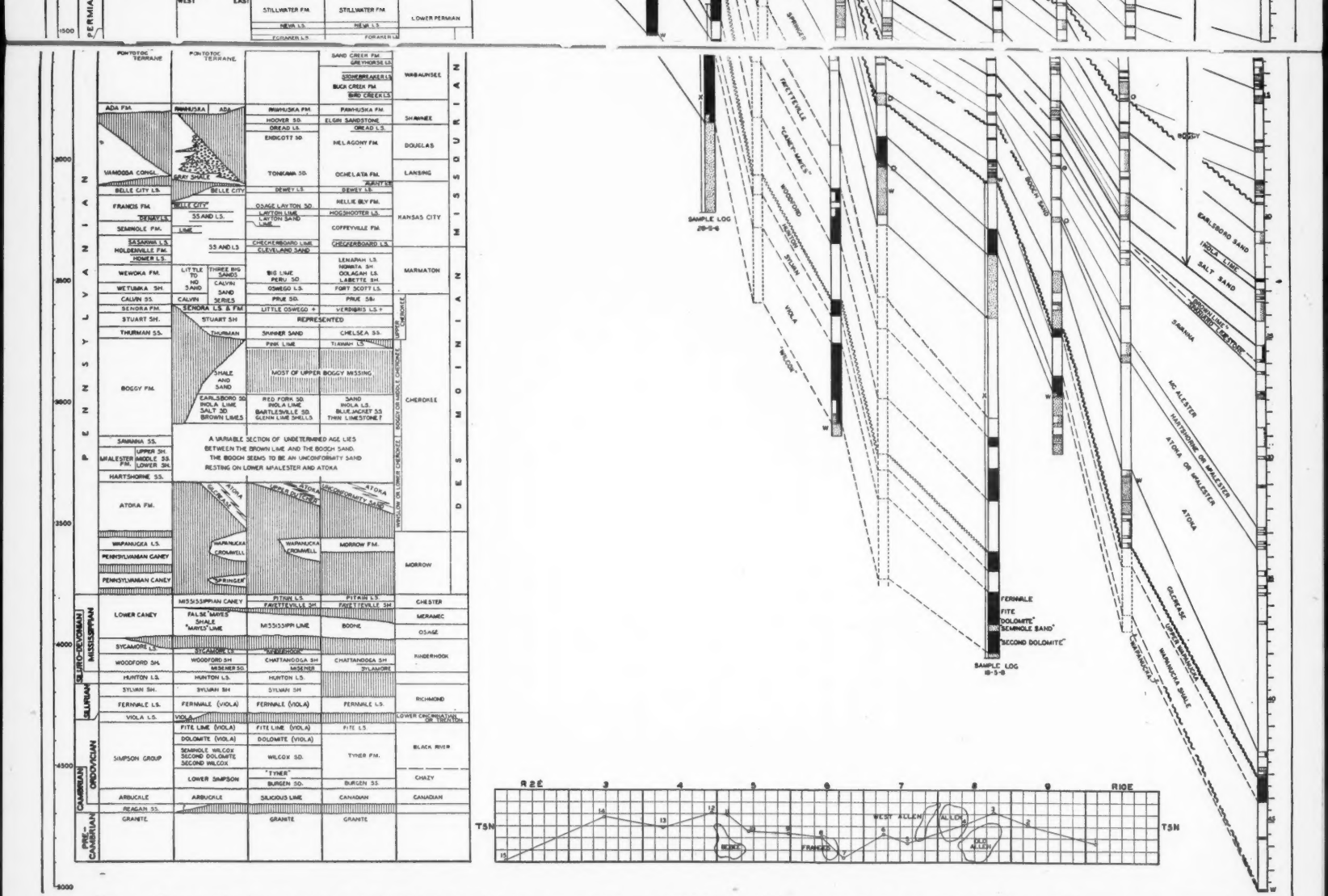
M. L. Thompson, *op. cit.* (1936).

———, "The Fusulinids of the Atoka and Boggy Formations," *Jour. Paleon.*, Vol. 9 (1935), pp. 291–306.

[71] Norman D. Newell, "Late Paleozoic Pelecypods: Mytilacea," *Kansas Geol. Survey*, Vol. 10, Pt. 2 (1942), Tables 2 and 3.

[72] C. H. Dane, H. E. Rothrock, and James Steele Williams, "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field, Part 3, the Quinton-Scipio District, Pittsburg, Haskell, and Latimer Counties," *U. S. Geol. Survey Bull. 874-C* (1938), pp. 163–65 and Pl. 15.


EAST-WEST STRATIGRAPHIC SECTION
T.5N. R.2-10E.
MC CLAIN-PONTOTOC-SEMINOLE AND HUGHES COUNTIES OKLAHOMA
DATUM TOP CALVIN SAND
HORIZONTAL SCALE 1 MI.
-LEGEND-
SHALE
SANDSTONE
LIMESTONE
RED ROCK
OIL
OIL SHOW
WATER
GAS
GAS SHOW
UNCONFORMITY
INTERPRETED FROM SURROUNDING DATA
MID-CONTINENT PETROLEUM CO.
CORRELATION BY SHEPARD W. LOWMAN
REVISED 1933
15 TEXL OIL HALVORSON NO1 EL. 1016
14 HOMACLA OIL NEWTON NO1 EL. 975
13 DOAN OIL CO. COOK NO1 EL. 1086
12 GILLESPIE & SONS TAYLOR NO1 EL. 1047
11 AMERICAN OIL & REF. JONES NO1 EL. 1007
10 SINCLAIR OIL & GAS GORDON NO1 EL. 1012
9 O.OWENS WELTY NO1 EL. 1083
8 T.B.BUCK WALKER NO1 EL. 1039
7 AMERICAN OIL & REF. CLAUDE LOGSDON NO1 EL. 990
6 INDEPENDENT OIL & GAS BROWN NO1 EL. 931
5 MID-CONTINENT PET. SCROGGINS NO1 EL. 794
4 HOMACLA OIL CO. WATSON NO1 EL. 831
3 TEXAS PACIFIC C&O GILMORE NO1 EL. 769
2 E.W.WHITNEY MOORE NO1 EL. 892
1 EV.ERWIN JONES NO2 EL. 979
ADA
VAMOOSA
PONTOTOC
LOWER VAMOOSA
FRANCIS
SEMINOLE
HOLDENVILLE
WEWOKA
WETUMKA
CALVIN
HUNTON
SYLVIN
VIOLA
HENRYHOUSE
COMMERCIAL
FERNVALE
MIDDLE VIOLA
"FIVE" REFERENCE LINE
"SEMINOLE SAND ZONE"
"SEMINOLE SHALE ZONE"
"GREEN SHALE" DOLOMITE
"GREEN SHALE" ZONE OF 2ND DOLOMITE
"WILCOX" OR 2ND SAND
"WILCOX"
SENORA
SENORA LIME
STUART
THURMAN
DATUM PLANE
GUERTIE SAND-PLEISTOCENE
GUERTIE SAND
BELLE CITY
BESSIES LINE
T.D.4290
T.D.4080
T.D.3310
T.D.2538
T.D.2852
T.D.1839
SAMPLE LOG PRE-PENNSYLVANIAN 29-5-3
AGE
OKLAHOMA
SOUTH CENTRAL
OUTCROP
UNDERGROUND
WEST
EAST
NORTH CENTRAL
UNDERGROUND
OUTCROP
STANDARD SECTION
PERMIAN
STILLWATER FM.
NEVA LS.
FORAKER LS.
LOWER PERMIAN
PONTOTOC TERRANE
SAND CREEK FM.
GREYHORSE LS.
STONEBRAKER LS.
BUCK CREEK FM.
SAND CREEK LS.
WABAUNSEE
CHEROKEE
CROMWELL
SPRINGER
MISSISSIPPIAN
MANNING
TRENTON
WILCOX
ARBUCKLE


PONTOTOC TERRANE
PONTOTOC TERRANE
STILLWATER FM.
STILLWATER FM.
NEVA LS.
NEVA LS.
FORAKER LS.
FORAKER LS.
LOWER PERMIAN
PERMIAN
1500
SAND CREEK FM.
GREYHORSE LS.
STONEBRAKER LS.
BUCK CREEK FM.
BIRD CREEK LS.
WABAUNSEE
ADA FM.
ADA
PAWHUSKA FM.
PAWHUSKA FM.
HOOVER SD.
ELGIN SANDSTONE
SHAWNEE
DREAD LS.
DREAD LS.
ENDICOTT SD.
HELAGONY FM.
DOUGLAS
2000
VAMOOSA CONGL.
GRAY SHALE
TONKAWA SD.
OCHELATA FM.
LANSING
BELLE CITY LS.
BELLE CITY
DEWEY LS.
AGNEW LS.
FRANCIS FM.
BELLE CITY
OSAGE LAYTON SD.
NELLIE BLY FM.
DENAYLE
55 AND LS.
LAYTON LIME
HOGSHOOTER LS.
SEMINOLE FM.
LIME
LAYTON SAND LIME
COFFEYVILLE FM.
KANSAS CITY
SASAKWA LS.
55 AND LS.
CHECKERBOARD LIME
CHECKERBOARD LS.
HOLDENVILLE FM.
CLEVELAND SAND
HOWER LS.
LENAPAH LS.
2500
WEWOKA FM.
LITTLE TO NO SAND
THREE BIG SANDS
BIG LIME
NOWATA SH.
OOLAGAH LS.
MARMATON
WETUMKA SH.
CALVIN SAND
PERU SD.
OSWEGO LS.
LABETTE SH.
FORT SCOTT LS.
CALVIN SS.
CALVIN
SERIES
PRUE SD.
PRUE SS.
SENORA FM.
SENORA LS. & FM
LITTLE OSWEGO ?
VERDIGRIS LS.?
UPPER CHEROKEE
STUART SH.
REPRESENTED
THURMAN SS.
THURMAN
SKINNER SAND
CHELSEA SS.
PINK LIME
TIAWAH LS.
SHALE AND SAND
MOST OF UPPER BOGGY MISSING
3000
BOGGY FM.
EARLSBORO SD.
INOLA LIME
SALT SD.
BROWN LIMES
RED FORK SD.
INOLA LIME
BARTLESVILLE SD.
GLENN LIME SHELLS
SAND
INOLA LS.
BLUEJACKET SS.
THIN LIMESTONE?
BOGGY OR MIDDLE CHEROKEE
CHEROKEE
SAVANNA SS.
A VARIABLE SECTION OF UNDETERMINED AGE LIES BETWEEN THE BROWN LIME AND THE BOOCH SAND. THE BOOCH SEEMS TO BE AN UNCONFORMITY SAND RESTING ON LOWER MCALESTER AND ATOKA
UPPER SH.
MCALESTER FM.
MIDDLE SS.
LOWER SH.
HARTSHORNE SS.
WINDLOW OR LOWER CHEROKEE
3500
ATOKA FM.
ATOKA
ATOKA
ATOKA

evidence of hiatus in these outcropping beds. The terms upper and lower Boggy no doubt need to be used with much caution. As previously noted, the upper Boggy beds in the McAlester basin area have been correlated with the Kittanning and the lower Boggy with the Clarion group. Evidently a separate name is needed for the 1,000 feet or more of the upper Boggy (Kittanning) beds of the McAlester area which lap out 50 miles west, on the east flank of the Henryetta flexure. This flexure trends northward through the Stonewall district and all the Boggy of that area is probably of Clarion age. The stratigraphic cross section by Lowman (Fig. 1) illustrates these relationships and shows other important features to which attention is called, including:

(1) the unconformity between lower and upper Boggy beds; truncation of 150 feet of lower Boggy beneath overlapping upper Boggy, the latter decreasing in thickness from 800 feet to 0 between R. 10 E., and R. 5 E. (30–60 miles west of McAlester);

(2) extension of wedge of upper Savanna and lower Boggy beds (including "Brown lime" and the "Salt" or Bluejacket sandstone) westward beyond probable limits of the McAlester, Hartshorne, and Atoka beds;

(3) regional overlap by the Hartshorne-lower Boggy section over truncated Atoka beds;

(4) truncation of Wapanucka (Morrow) and older beds beneath progressive overlap of Atoka, Hartshorne, McAlester, Savanna, Thurman, and Senora beds;

(5) progressive westward loss by overlap not only of 800 feet of upper Boggy but of 1,000 feet of Thurman and lower Senora beds. These upper Cherokee beds are shown making contact progressively with lower Boggy, upper Savanna, Springer, and older beds down to the Hunton and Viola limestones.

As indicated in Figure 2 and discussed later, the regional structure in north-central Texas between the Fort Worth basin and the Bend flexure-Concho arch has many similarities with the McAlester basin and Henryetta flexure-Hunton arch in Oklahoma.

Dane, Rothrock and Williams[73] concluded that the marked thinning of beds in anticlinal features of the McAlester basin was caused by recurrect diastrophic movements from Morrow to Boggy time. After completing much detailed structural mapping in the area, Clawson asserted that

> the large steeply folded structural features typical of the Coalgate-McAlester area and associated with the Ouachita overthrust were well developed by middle and late Boggy time, subsequent folding consisting more of a tilting and gentle warping effect with compressive forces active from the northeast and southwest rather than from the direction of the Ouachita mass to the south east.[74]

The views of Lowman and Clawson are supported by Harlton's conclusion that

[73] C. H. Dane, H. E. Rothrock, and James Steele Williams, *op. cit.* (1938), pp. 192–96, 250.

[74] W. W. Clawson, Jr., "Oil and Gas in Oklahoma, Coal and Pittsburgh Counties," *Oklahoma Geol. Survey Bull. 40*, Vol. III (1930), p. 408.

"the final culmination of the Ouachitas undoubtedly occurred after Morrow in late Boggy time, which records the last definite evidence of movement."[75] However, regional uplift after the period of active folding and thrusting is indicated by the character and quantity of detrital material including the distinctive chert conglomerates in the Des Moines-Strawn and later deposits observed locally between Seminole, Oklahoma, and McCulloch County, Texas, and regional tilting during late Pennsylvanian and Permian time. Vari-colored chert beds of the Ouachita region are the only known adequate source of these unique chert gravels.

3. *Base of Bluejacket sand.*—The base of this economically important member of the lower Boggy offers the advantage of more definite position and widespread recognition. However, the upper Tradewater-Clarion zone fossils such as *Spirifer opimus* and *Fusulina leei* occur above this sandstone. Also this sandstone is involved in the strong folding of the late Ouachita orogeny as shown by northeastward trending faults with vertical displacement of as much as 600 feet (basal McAlester shale opposite shales below Taft sandstone of the middle Boggy, southern suburbs of Muskogee) and folds with flanks dipping at the rate of 25°.[76]

4. *Base of persistent lower Boggy shale member.*—This shale member as described by Wilson and Newell[76a] overlaps a basal Boggy shale section 160 feet thick with included thin sandstone and fossiliferous limestone containing upper Pottsville brachiopods as already mentioned. Again objection may be made on structural grounds. This and lower unconformities appear to represent recurrent phases of the Ouachita orogeny on the east and progressive development on the west of the Hunton arch and related major features between the deeply subsiding McAlester and Anadarko basins.

5. *Between McAlester and Savanna.*—A prominent unconformity between these beds is indicated in most regional cross sections. Hendricks[77] cites evidence of unconformable contact at the outcrop between McAlester and Savanna beds. The increased proportion of sandstone in the Savanna suggests renewed folding and uplift of the Ouachita region and Hunton arch at this time. Apparent absence of *Mesolobus* in the beds older than Savanna in the Muskogee area does not hold elsewhere. In the Ardmore basin *Mesolobus striatus* occurs down to the Lester limestone of the middle Dornick Hills section, in the zone of *Fusulinella. Neuropteris desorii*, which first appears in the Kittanning coal group, occurs in abundance in the basal coal of the Boggy and underlying shales. The McAlester-Savanna boundary offers a mid-way compromise between lowest and highest positions proposed for separation of the Lampasas and Des Moines series.

[75] Bruce H. Harlton, *op. cit.* (1938), pp. 863–64.

[76] Charles W. Wilson, Jr., and Norman D. Newell, *op. cit.* (1937), pp. 51–56 and Pl. III.

[76a] *Ibid.*

[77] Thomas A. Hendricks, "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field, Part 1, The McAlester District, Pittsburg, Atoka, and Latimer Counties," *U. S. Geol. Survey Bull. 874-A* (1937), pp. 14–17, Pl. 1.

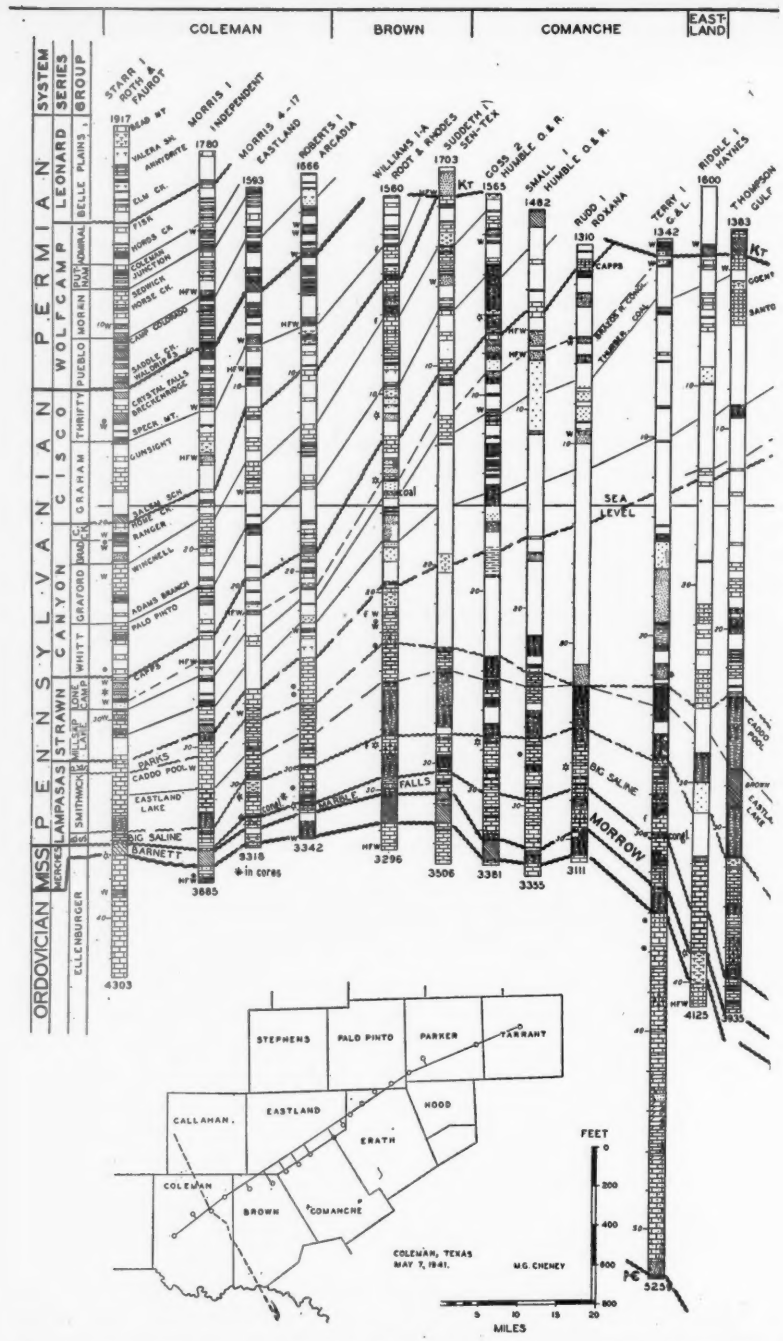
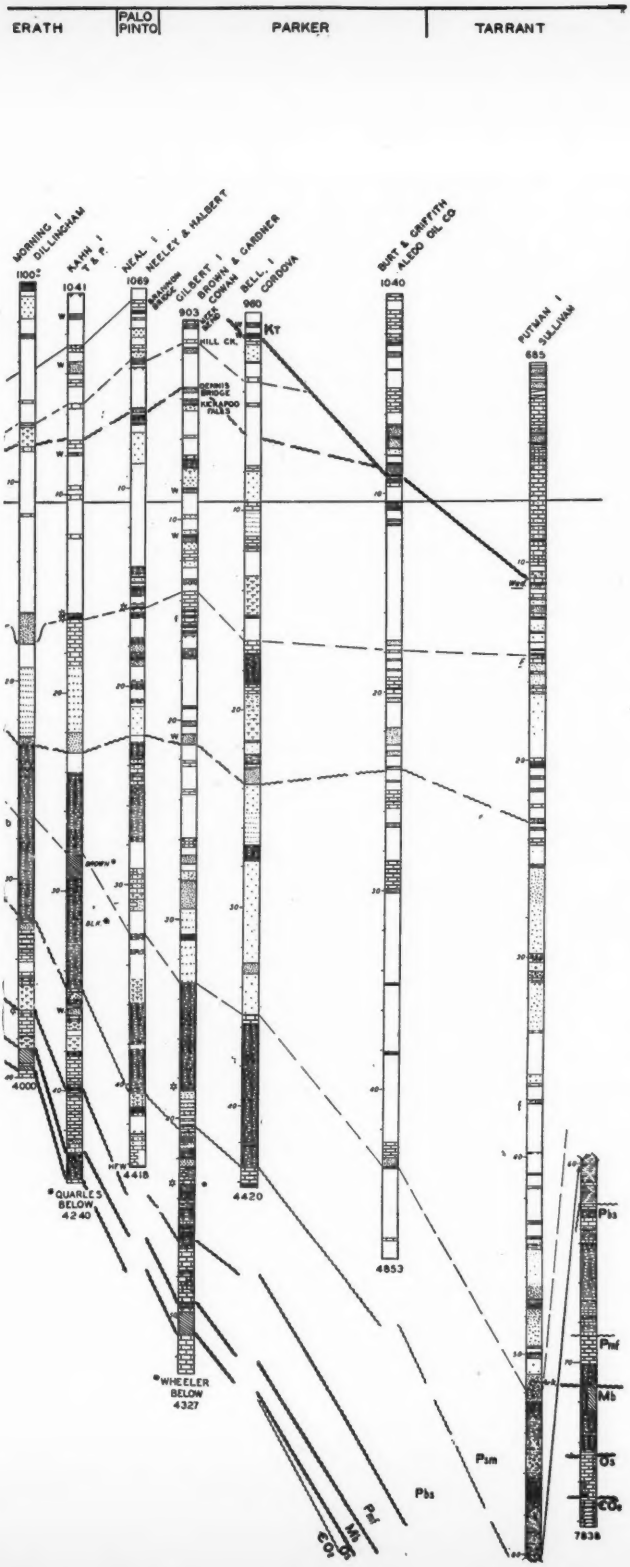



FIG. 2.—Cross section from Fort Worth basin southwest 150 miles to western Coleman County, Texas, crossing Bend flexure and approaching Concho arch. Loss of upper Lampasas and lower Strawn beds resembles that of Atoka-Calvin section in eastern Oklahoma. Unconformity between Lampasas and Strawn series becomes pronounced in more positive areas as shown in Figure 3.


ERATH
PALO PINTO
PARKER
TARRANT
WORNING & DILLINGHAM
1100
KAHN & T. & P.
1041
NEAL
1069
NEELEY & HALBERT
GILBERT & BROWN & GOWAN
903
BELL & CORDOVA
980
BURT & GRIFFITH ALLDO OIL CO
1040
PUTMAN & SULLIVAN
685
HILL CR.
DENNIS BRIDGE
KICKAPOO FALLS
Kt
BROWN
BLK.
4000
HFW
4418
4420
4853
7838
*QUARLES BELOW 4240
*WHEELER BELOW 4327
Pbs
Pmf
Mb
Os
CO3
Psm
Pbs
Pmf
Mb
CO3

6. *Between Atoka and Hartshorne.*—An important unconformity is reported at this position over considerable area. As previously noted, plants from Hartshorne to lower Boggy beds have been correlated with the Clarion group, those of the Atoka being pre-Clarion and classified definitely as Pottsville. Faunal changes are notable and distinctive to an important degree. Development of the genera *Fusulina* and *Wedekindellina* came mainly but not entirely in post-Atoka time, the Atoka being recognized as the zone of *Fusulinella*. Pronounced unconformities are reported within the thick type Atoka section;[78] hence, it is thought to represent a considerable length of time and a complex geologic history. Use of Atoka-Hartshorne boundary for separation of Lampasas from Des Moines series seems logical if Clarion beds of the type section are finally included in the Allegheny rather than in the upper Pottsville-Kanawha series. If the Atoka division is not given the rank of series it might be given the rank of group; and, if the time-rock term stage is to be used for Paleozoic rock divisions as it is in Europe and as it has been introduced for Mesozoic and Cenozoic rocks of the United States, this division could appropriately be called the Atoka stage.

### TYPE LAMPASAS SECTION AND CORRELATIVES

"Beds younger than Morrow, but older than type Strawn of the Brazos River Valley section" were designated the Lampasas series in a paper completed in 1939 as part of a symposium on the geology of West Texas and New Mexico.[79] The Morrow and Strawn referred to were intended to have the same time-stratigraphic limitations as the Morrow and Des Moines series of the northern Mid-Continent section.

Bend, Bendian, Atoka, and Winslow were considered and rejected in naming this needed new series. Continued use of Bend as a name for both Marble Falls and Smithwick beds of Morrow and post-Morrow age seemed desirable. Bend, Bendian, and Winslow had been used with variable meaning. The United States Geological Survey had officially abandoned the name Winslow for this reason, and its revival was, and still is, much opposed by geologists in Oklahoma. Atoka was thought not sufficiently inclusive and was needed as used. Some new name from the region under discussion seemed most appropriate. The name Lampasas was proposed because of important outcrops of this series in Lampasas County, Texas.

The type section of the Lampasas series is located around the Llano uplift of central Texas and in the area north thereof. McAnnelly's Bend in the vicinity of the village of Bend in San Saba and Lampasas counties has been used as the type area of the Bend division. As indicated in Figure 3, the lower 80 feet or more of shales heretofore called Smithwick at Bend change westward to limestone with Big Saline *Fusulinella* and other post-Morrow fauna. To clarify time-

[78] Thomas A. Hendricks, personal communication, December, 1943.

[79] M. G. Cheney, "Geology of North-Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 65–118.

stratigraphic relationships, it seems desirable to: (1) restrict use of the name Marble Falls to beds of Morrow age; (2) refer to the superjacent division of limestones, conglomerates, sandstones, and shales as the Big Saline group instead of "upper Marble Falls"; and (3) restrict the use of the term Smithwick to the remaining upper part of the outcropping Bend rocks. Certain overlying beds (called Caddo or Parks) have commonly been included in the Bend of the subsurface but excluded from the Bend of the outcrop section. Presumably this dual usage will continue, and the name Bend thus will be used as a broad term with variable meaning to include rocks of both the Morrow and younger series.

Separation of Morrow equivalents from the post-Morrow is aided in some areas by the presence of a basal chert conglomerate and coarse sandstone zone which increases in thickness from a few feet in central Texas to several hundred feet in Montague County and the Ardmore basin. The discovery well of the Ranger field produced oil from this basal sandstone. *Fusulinella* are found down to, but not below, the base of this conglomerate zone.

The pre-Big Saline Pennsylvanian limestones are commonly cherty and massive. These rocks have a thickness of about 250 feet at Marble Falls and 200 feet near Bend. Presumably as a result of pre-Big Saline truncation, they decrease in thickness and are absent at the outcrop and in wells 50 miles to the west of Bend.

Early upper Pottsville primitive *Fusulinella* in the lower Big Saline are followed by higher types of *Fusulinella* in the upper Big Saline and Smithwick beds. The post-Smithwick, Parks group contains early *Fusulina* and *Wedekindellina* like those of the Savanna and lower Boggy, upper Tradewater and Clarion group of Oklahoma, Illinois, and eastern Ohio, respectively.

Structural and stratigraphic relationships of rocks from the Ellenburger to top of the Canyon series for a distance of 110 miles northwest from Bend, Texas are shown in Figure 3. The following summarized well records also give information concerning Strawn, Lampasas, and older beds in eastern San Saba County.

WELL NO. 17 IN FIGURE 3

1.5 MILES WEST OF VILLAGE OF BEND

C. D. Lane–J. E. McCoury No. 1
A. Dietz Survey No. 45

Pennsylvanian system
Lampasas series

| | | |
|---|---|---|
| 0–120 | shale, olive to dark gray | Smithwick |
| –204 | shale, dark gray to black | Big Saline |
| –257 | limestone and shale, black | Big Saline |
| –295 | limestone, cherty, gray, brown | Big Saline |
| –332 | limestone, *Fusulinella* | Big Saline |
| –342 | limestone | Big Saline |
| –347 | sandy shale, grayish black | Big Saline |

Morrow series

| | | |
|---|---|---|
| –420 | limestone cherty, shale, gray to black | Marble Falls |
| –423 | limestone and shale, *Staffella* | Marble Falls |
| –550 | limestone | Marble Falls |

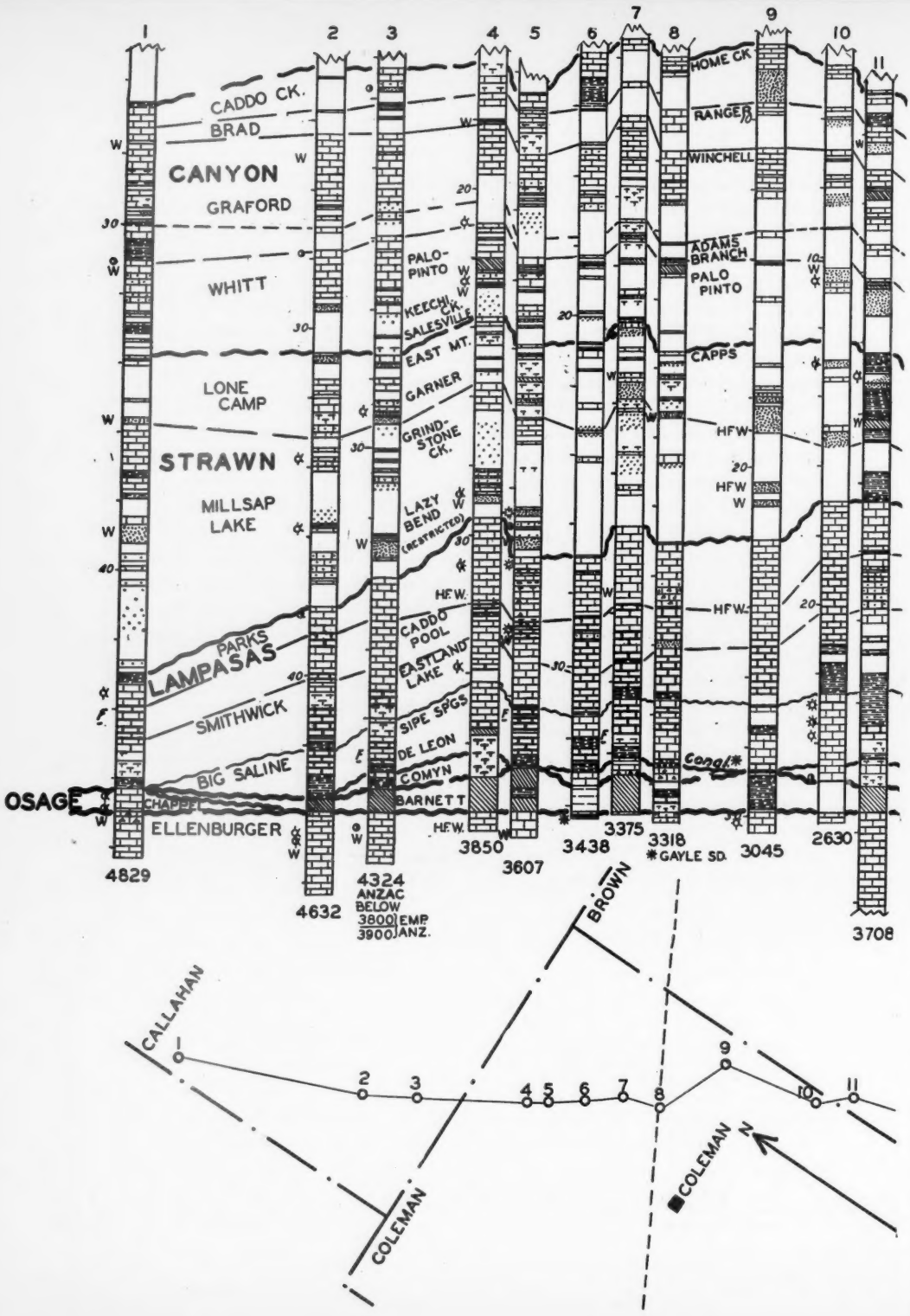
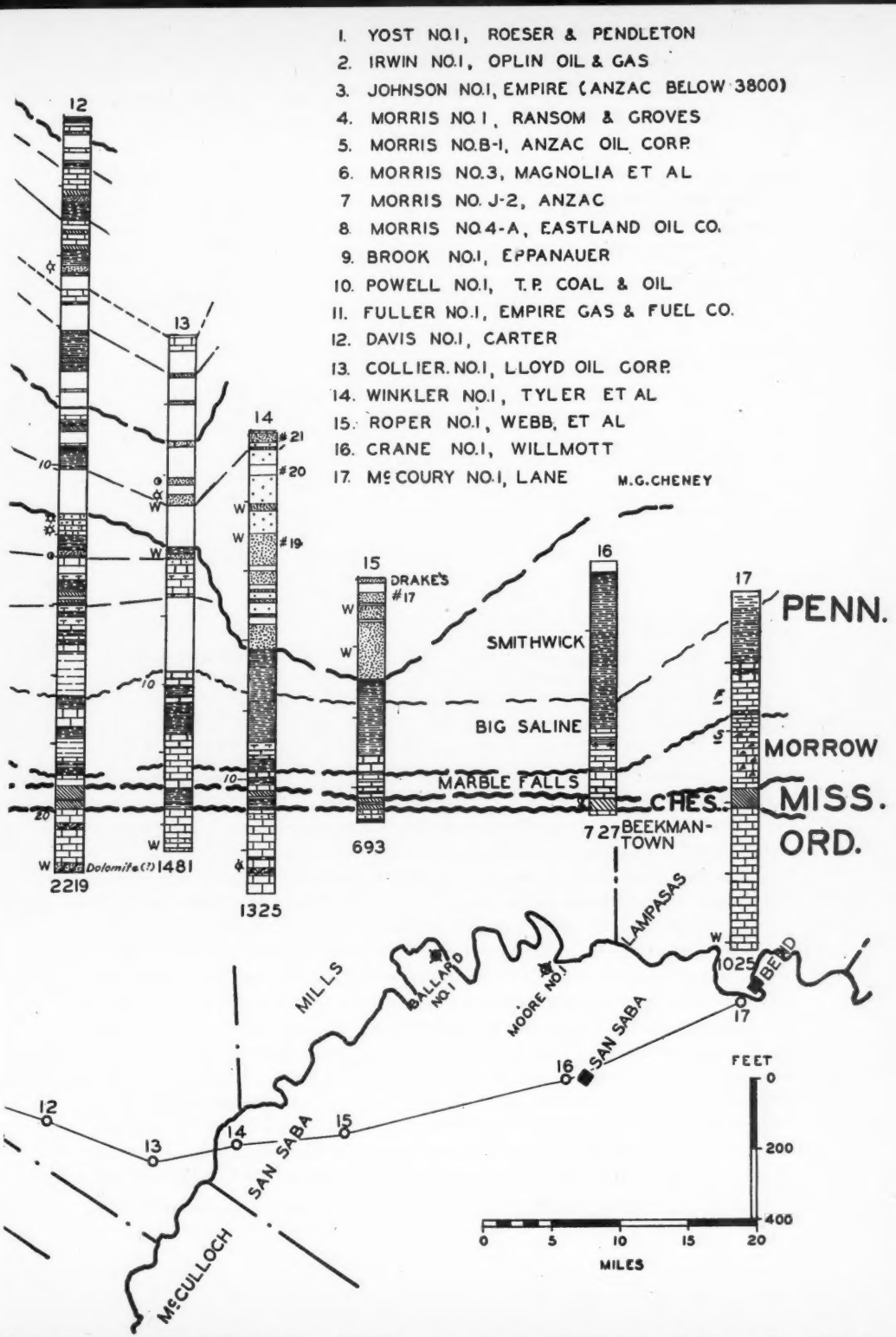



FIG. 3.—Cross section extending 110 miles northwest from type area of Bend division, eastern San Saba County, to western Callahan County, Texas, showing: (1) westward loss of Marble Falls beds containing *Staffella* and *Millerella;* (2) change from shale to limestone of lower *Fusulinella* zone called Big Saline group; (3) westward change from shale to limestone of upper




*Fusulinella* zone, Eastland Lake formation; (4) Caddo Pool formation, typically black dense limestone siliceous due to abundant sponge spicules, lacking fusulinids, herein classified with the Eastland Lake as the Smithwick group; (5) marked lithologic change and unconformity at top of Parks group taken as boundary between Lampasas and Strawn series.

| | | |
|---|---|---|
| Mississippian system | | |
| Chester series, Meramec series (?) | | |
| –612 | shale, brown to black | Barnett |
| Osage series | | |
| –620 | limestone, gray | Chappel |
| Ordovician system | | |
| Beekmantown series | | |
| –1025 | limestone and dolomite white, gray | Ellenburger |

14 MILES NORTHWEST OF VILLAGE OF BEND

Bud Willmott–Mrs. J. A. Moore No. 1
J. A. Hernandez Survey No. 78

| | | |
|---|---|---|
| 0– 130 | sandstone; shale blue; thin limestones, Drake's Fox Ford bed | Millsap Lake |
| – 242 | shale, dark, thin ss. Bed No. 8 | Millsap Lake |
| – 661 | shale, dark to gray, calcarous | Smithwick |
| – 732 | shale, dark to black, hard | Big Saline |
| – 846 | limestones, brown or gray, thin shale, black | Big Saline |
| – 871 | conglomerate, thin lime, and shale, black | Big Saline |
| – 975 | limestone, brown, white, hard | Marble Falls |
| – 985 | limestone, black, hard | Marble Falls |
| –1,046 | shale, dark brown | Barnett |
| –1,048 | limestone, gray | Chappel |
| –2,000+ | limestone, dolomite, white, gray | Ellenburger |

23 MILES NORTHWEST OF VILLAGE OF BEND

Three Widows Oil Co., Mrs. M. E. Ballard No. 1
H. Behrenroth Survey 506

| | | |
|---|---|---|
| 0–1,005 | sandstone and shale, Drake's beds 13 to 7 | Millsap Lake |
| –1,400 | shale, dark gray to black | Smithwick |
| –1,600 | shale, black; thin ls., brown | Big Saline |
| –1,675 | lime and shale, black | Big Saline |
| –1,680 | chert conglomerate | Big Saline |
| –1,820 | lime, black, gray | Marble Falls |
| –1,891 | shale, brownish black | Barnett |
| –1,893 | limestone gray | Chappel |
| –1,962 | limestone, white, gray | Ellenburger |

Differentiation of Marble Falls from Big Saline beds is rendered difficult in some areas because gray to black limestones occur both below and above the common boundary. Also, Big Saline limestones containing one or more zones of *Fusulinella* change to shales or to limestones in which these fossils are rare or absent as in the area of outcrop of central and eastern San Saba county. Such lithologic changes in the subsurface account for stratigraphic trapping of oil and gas in several north-central Texas fields, including the 12 mile long Santa Anna gas field in eastern Coleman County (compare wells 10 and 11 of Figure 3) where limestone grades laterally to black shale within a distance of less than one mile. This narrow transition zone can be traced many miles along a northeast trend. Similar conditions occur in the vicinity of Carbon in Eastland County and Sipe Springs and DeLeon in Comanche County, Texas. Local reef developments in these beds have been noted in the outcrop and found by drilling in this region.

The DeLeon or lowest subsurface formation of the Big Saline group, Lampasas series, is thought to be equivalent to much of Moore's[80] middle Marble Falls

[80] Raymond C. Moore, "The Bend Series of Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), p. 223.

limestone in the Rough Creek locality 4 miles northwest of Bend. His faunal list (p. 227) includes post-Morrow brachiopods such as *Chonetes* (*Mesolobus*) *mesolobus* and *Spirifer rockymontanus*. Much of his upper Marble Falls (some duplication?) section as measured near the village of Bend along with most of the overlying black fissile shales and thin beds of black limestone may be correlated with the Sipe Springs formation, upper Big Saline group of the subsurface.

Additional evidence on classification of the relatively non-fossiliferous section at Marble Falls may be derived from the *Fusulinidae*. The ancestral genus *Staffella* is reported as low as the Viséan in the Samara Bend section of U.S.S.R., according to Rauser-Cernoussova and others. Successive development of new genera has been discussed by Thompson[81] who reported the most primitive fusulinids from North America that he had studied came from the Brentwood limestone member of the Boyd shale of the Morrow series. These were classified by him as primitive *Millerella*. The second earliest type from North America was his discoidal *Millerella marblensis*, from 150 feet below the top of the Marble Falls beds at the type locality in Texas and from basal beds of his Derry series in New Mexico. *Profusulinella*, which first appears well above the base of the Derry series marks the third stage. This he says is "a genus more highly developed biologically than any fusulinids found in the type section of the Marble Falls limestone." A fourth stage is the *Fusulinella* zone as found in the Big Saline and Smithwick groups of the Lampasas series, and the Mud Springs group of the upper Derry series. Thompson considers *Millerella marblensis* from the basal Derry and upper Marble Falls as not greatly younger stratigraphically than the most primitive *Millerella* from the Brentwood. By bearing in mind that the Brentwood is generally correlated as of early or possibly middle Morrow age (Union Valley limestone), also that very *primitive Fusulinella* appear in *basal* Atoka beds, it appears reasonable to think that these fusulinids from the type Marble Falls and basal Derry sections may be of late Morrow rather than early Lampasas age. The discoidal shape of *Millerella*, antedating the spindle shape of *Fusulinella fittsi* supports assignment to the Morrow.

As previously discussed, a widespread unconformity occurs between beds correlated with the Morrow and succeeding beds of the Lampasas series. The thin limestone conglomerate 115 feet below the top of the limestone section at Marble Falls may represent this hiatus between Morrow and Lampasas beds.[82] Big Saline beds are known to overlap progressively older beds in north-central Texas as shown in Figure 3. In eastern McCulloch County, Texas, 4 miles southwest of Rochelle, *Fusulinella*-bearing limestones about 125 feet thick rest on the Mis-

[81] M. L. Thompson, "Pennsylvanian System in New Mexico," *New Mexico Bur. Mines and Min. Resources Bull. 17* (1942), pp. 29–30.
———, "New Genera of Pennsylvanian Fusulinids," *Amer. Jour. Sci.*, Vol. 240 (1942), pp. 403–20.

[82] Sidney Paige, "Llano-Burnet," *U. S. Geol. Survey Geol. Folio 183* (1912), p. 8.

sissippian Barnett shale, and on the Ordovician Ellenburger limestone in wells farther west.

The Morrow and Lampasas series differ lithologically as may be noted in descriptions by Goldman.[83] The boundary between these series should evidently be placed between divisions I and J of Goldman at the depth of 4,132 feet in the Roxana Petroleum Corporation's Seaman No. 1. As identified by M. L. Thompson and others (1941), Atoka-Lampasas types of *Fusulinella* without *Fusulina* are locally abundant as high as upper Eastland Lake formation; for example, from a depth of 4,010–4,025 feet in the Anzac Oil Corporation's E. S. Graham No. 2, Young County, Texas.[84]

Local erosion of Smithwick shales and westward loss of 2,500 feet of over lying beds below upper Strawn are revealed in the Llano uplift region of central Texas between Lampasas and McCulloch counties. Evidently the post-Smithwick beds were deposited during and after the development of much rifting and irregular subsidence of a deep trough trending northeast. Thicknesses vary greatly between alternating graben and horst areas. The middle and upper parts of this post-Smithwick sandstone and shale sequence show only minor reflection of the northeast-trending pronounced faults and folds having structural relief in the underlying Bend limestones of as much as 1,000 feet. Like the Henryetta flexure and Hunton arch in Oklahoma, the Bend flexure and Concho arch were gaining prominence in northern and central Texas near the close of Lampasas time. Westward regional tilting has given the Bend flexure the appearance of an extensive arch. It has, however, obscured the earlier dominance of the Concho arch, which doubtless was much uplifted and furnished much of the clastic material deposited in the near-by Strawn and Kerr basins,[85] especially in late Lampasas and early Strawn time. Important structural and lithologic changes occur in the subsurface of north-central Texas between the Strawn series and upper part of the "subsurface Smithwick" or Parks beds. Cores taken just below the top of a limestone correlated as upper Parks in central Coleman County contain early *Fusulina* and *Wedekindellina* like those found in the Dennis Bridge beds of the Brazos River outcrop section and the Boggy (Stonewall area?) of Oklahoma according to Thompson.[86] Henbest[87] has identified the following species from these cores: *Wedekindellina euthysepta* (Henbest), *W. ellipsoides* (Dunbar and Henbest), *W. excentrica* (Roth and Skinner), *Fusulina* aff. *rockymontana* (Roth and Skinner), *F. distenta*? (Roth and Skinner). *Wedekindellina euthysepta* and *Fusulina novamexicana* are reported from the Kickapoo Falls and Dennis Bridge limestones of the outcrop section,[88] thus supporting correlation of these

[83] Marcus I. Goldman, "Lithologic Subsurface Correlation in the 'Bend Series' of North Central Texas," *U. S. Geol. Survey Prof. Paper 129-A* (1921).

[84] See M. G. Cheney, *op. cit.* (1940), p. 84, Fig. 5, for comparison of Seaman and Graham wells.

[85] E. H. Sellards, "Geology of Texas," *Univ. Texas Bull. 3401* (1934), Fig. 1, p. 88.

[86] M. L. Thompson, personal communication, March 30, 1942.

[87] Lloyd G. Henbest, personal communication, August 11, 1943.

[88] Carl O. Dunbar, Lloyd G. Henbest, and J. Marvin Weller, *op. cit.* (1942), pp. 100, 113–15.

subsurface and surface sections with the Savanna and lower Boggy of Oklahoma and the upper Tradewater of Illinois. As previously discussed, the flora and fauna of these beds indicate pre-Kittanning age.

Fusulinids in shales just above the Parks beds of the subsurface have been identified as of the same age as those of the Hill Creek beds about 200 feet above the Dennis Bridge limestone (Fig. 2). It is now proposed that the Lampasas-Strawn boundary in the Brazos River outcrop section be placed at the base of the conglomerate which rests on the Dennis Bridge limestone at the Dennis highway bridge in southwestern Parker County, Texas. Assignment of the Parks beds to the Lampasas series seems particularly appropriate if the Clarion group of the type Pennsylvanian is to be classified as upper Pottsville as now seems desirable.

Placement of Connoquenessing, Mercer, and Clarion groups of Pennsylvania in the Kanawha series (upper Pottsville) favors inclusion of the approximately equivalent Big Saline, Smithwick, and Parks groups in a correlative series of the Mid-Continent region, the Lampasas series.

The Parks beds are herein considered more appropriately classified as a group rather than a formation. The Parks group typically consists of a variable sequence of dark shales, limestones, and sandstones between the black shales, gray, black, and siliceous limestones of the Smithwick group and an unconformity at the base of the conglomerates, sandstones, blue shales, and limestones of the Strawn series. In the Brazos River outcrop section this unconformity is placed at the base of the chert conglomerate overlying the Dennis Bridge limestone at Dennis in southwestern Parker County. Drilling indicates a thickness of about 1,600 for the Parks group near Dennis. Westward, depositional thinning and truncation reduce the Parks group to 200–300 feet in its type subsurface area in Stephens County.[89]

The Lazy Bend formation, Millsap Lake group and Strawn series of the Brazos River outcrop section are preferably restricted to beds above the Dennis Bridge limestone at Dennis.

Beds below the chert conglomerate at Dennis Bridge and above the Kickapoo Falls limestone may be referred to as the Dennis Bridge formation.

The Kickapoo Falls limestone may well be classified as the top member of the Dickerson formation in harmony with common practice in this region of placing an important limestone at the top of a formation.

Paleobotanic data, when secured, should greatly aid in determining the position of the Lampasas-Strawn boundary in the sandstones and shales of the Colorado River section. Absence of Drake's beds[90] No. 4 to No. 7 in eastern San Saba County (Willmott's Moore No. 1) and the rapid eastward dip noted in these beds in western Lampasas County suggest that they were deposited prior to the diastrophism which came near the close of the Lampasas epoch; hence, beds at

[89] M. G. Cheney, *op. cit.* (1940), p. 86.

[90] N. F. Drake, *op. cit.* (1893), pp. 17–19 of 1917 reprint.

least as high as the Shadrick Mills sandstone, Drake's No. 7, and perhaps higher are thought to belong to the Parks group.

The extensive work by Plummer and Scott,[91] describing numerous ammonites from beds which they called the Marble Falls limestone, Smithwick shale, and Millsap Lake formation renders this type Lampasas section of central Texas of greater usefulness for purposes of interregional and intercontinental correlation. Reference to their text and Figures 1 and 83 indicates the following zonation, according to stratigraphic terminology of the present report.

| | Zone or Assemblage |
|---|---|
| Strawn (Des Moines) series | |
| Lone Camp group, upper | *Paraschistoceras strawnense* |
| lower | *Pintoceras postvenatum* |
| Millsap Lake group, upper | *Gastrioceras venatum* |
| Lampasas series | |
| Parks group, upper | *Pseudoparalegoceras brazoense* |
| Smithwick group | *Gastrioceras smithwickensis*[91a] |
| Big Saline group | *Phaneroceras compressum* |

The principle seems well established that a major time-stratigraphic division, whether system, series, or even lesser units, may be satisfactorily established in a general framework of classification even though the type area is separated geographically from preceding or succeeding divisions of equal rank. The type section of the Lampasas series of the Brazos, Colorado, and Llano river valleys compares favorably in most respects with the type sections of the other series of the Pennsylvanian. Thousands of wells in north-central Texas furnish much additional data and permit extensive stratigraphical, paleontological, and structural studies of this series of upper Pottsville age.

### TYPE DES MOINES SECTION AND CORRELATIVES

Rocks approximately equivalent to the Allegheny division have been called Strawn since 1890 in Texas, Des Moines since 1893 in the northern Mid-Continent and Deese since 1922 in the Ardmore basin. Boundaries and rank have been changed somewhat but these names have been retained in each geologic province.[92]

The Des Moines division was the first to be established on a time-stratigraphic basis.[93] During the past 12 years its upper boundary has consistently been placed at a widespread hiatus where a pronounced faunal change takes place. Such genera as *Fusulina*, *Mesolobus*, *Chaetetes*, and *Prismopora* and many others[94] are not known to be indigenous to rocks above the unconformity at the

[91] F. B. Plummer and Gayle Scott, "Upper Paleozoic Ammonites in Texas," *Univ. Texas Bull. 3701* (1937), pp. 1–516.

[91a] As revised by Plummer and Scott in personal communication, December, 1944.

[92] M. Grace Wilmarth, *op. cit.* (1938).

[93] R. C. Moore, "A Reclassification of the Pennsylvanian System in the Northern Mid-Continent Region," *Kansas Geol. Soc. Guidebook Sixth Ann. Field Conference* (1932), pp. 79–103.
———, "Stratigraphic Classification of Pennsylvanian Rocks of Kansas," *Univ. Kansas Bull. 22* (1936).

[94] R. C. Moore, *op. cit.* (1944).

base of the overlying Chariton conglomerate, Pleasanton formation, of southern Iowa and Missouri,[96] and equivalent Trivoli sandstone of Illinois, Inglefield sandstone of Indiana, Mahoning sandstone of Ohio and Pennsylvania, and the Warrensburg channel sandstone of western Missouri and eastern Kansas (basal Bourbon). As traced southwestward, this boundary between the Des Moines and Missouri series is placed at the hiatus marked by the base of the Seminole conglomerate in Oklahoma, the sandstone just above the Confederate limestone in the Ardmore basin, and the Lake Pinto sandstone in north-central Texas.

The Des Moines-Missouri boundary of the Mid-Continent seems to be in close agreement with the Allegheny-Conemaugh boundary of the type Pennsylvanian section. Appreciable revision of boundaries now in use are needed only in Eastern Interior region (post-Lonsdale unconformity), the Marathon region and in some of the western states to secure close agreement across the continent.

If the base of the Kittanning boundary is adopted as the Kanawha-Allegheny boundary in the Appalachian area, the base of the first sandstone below the White Breast coal would seem to be an appropriate Des Moines-Lampasas boundary in Iowa. Early species of *Fusulina* and *Wedekindellina*, found 30 feet below the White Breast coal, are evidently of Clarion age, whereas the fusulinids 90 feet below this coal include *Fusulinella iowensis* of Mercer age, according to Thompson.[96]

Both the type Allegheny and type Des Moines sections are relatively thin and presumably incomplete, having maximum thickness of only 300–400 feet, as compared with at least 3,000 feet assigned to this division in eastern Oklahoma, (upper Boggy to top of Marmaton), 5,000 feet in the Ardmore basin and 2,000 feet in north-central Texas (top of Dennis Bridge limestone to base Lake Pinto sandstone).

The cyclical deposition which is characteristic of a large part of the Pennsylvanian rocks of the Appalachian and Mid-Continent regions has received the attention of geologists since 1874.[97] In more recent papers[98] the application of these studies to problems of classification and interregional correlations is emphasized.

Choice of boundaries for the Deese series of the Ardmore basin section of

[95] L. M. Cline, "Traverse of Upper Des Moines and Lower Missouri Series from Jackson County, Missouri, to Appanoose County, Iowa," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), p. 70.
J. M. Weller *et al.*, *op. cit.* (1944), Fig. 1, and p. 1592.

[96] M. L. Thompson, "The Fusulinids of the Des Moines Series of Iowa," *Univ. Iowa Studies*, Vol. 16 (1934), pp. 277–332.
———, "Pennsylvanian Fusulinids from Ohio," *Jour. Paleon.*, Vol. 10 (1936), pp. 673–83.

[97] John S. Newberry, "Circles of Deposition in American Sedimentary Rocks," *Proc. Amer. Assoc. Adv. Sci.*, Vol. 22, Pt. 2 (1874), pp. 185–96.

[98] H. R. Wanless and J. M. Weller, "Correlation and Extent of Pennsylvanian Cyclothems," *Bull. Geol. America*, Vol. 43 (1932), pp. 1003–16.
R. C. Moore, *op. cit.* (1936), pp. 29, 32.
J. M. Weller *et al.*, *op. cit.* (1942).

reference offers some difficulties due to completeness of section and lack of sharp paleontologic demarcation. For example, fusulinids near the upper Deese boundary include transitional borderline forms between *Fusulina* and *Triticites;* hence, placement of this boundary between the Confederate and Union Dairy limestones is somewhat arbitrary. Study of ostracods led Bradfield[99] to place the Deese-Hoxbar boundary either at the base of the Confederate limestone or of a chert conglomerate somewhat lower.

Geologists specializing in the Ardmore basin area report that the rocks of that area are more readily correlated with the north-central Texas than with the northern Mid-Continent section. The unconformity between Des Moines and Missouri equivalents becomes much more pronounced in passing from the Ardmore basin to the northeast flank of the Concho arch. Fusulinids 1,000 feet below the Confederate limestone[100] are found in the Capps limestone member of the East Mountain shale formation, at the top of the Strawn series in Palo Pinto County. Another 120 miles southwest in east-central McCulloch County, the Capps limestone is absent, apparently by erosion, and the upper Strawn Brazos River conglomerate (resting on Big Saline limestone) is only 200 feet below the Adams Branch limestone of the Canyon series instead of 1,200 feet as in Palo Pinto County. Broad regional uplifts, deep channelling, and a marked faunal change characterize this hiatus between Middle and Upper Pennsylvanian rocks in the more positive areas.

Near the base of the Des Moines equivalent in the Ardmore basin, the abrupt change from open prairie land to rough wooded terrane in passing from outcrops of Pumpkin Creek beds to lower Deese in the Lake Murray district is striking evidence of a marked difference in lithology at this boundary. However, paleontologic evidence now seems to indicate the need of lowering the base of Deese to some boundary within the Pumpkin Creek beds if top of Dornick Hills is to be restricted to the zone of *Fusulinella*, or perhaps of raising this boundary to the base of the Devil's Kitchen formation if beds of Clarion age are included in the Lampasas series and the Dornick Hills-Deese boundary is changed accordingly.

### MONONGAHELA GROUP—VIRGIL SERIES
### CONEMAUGH GROUP—MISSOURI SERIES

The Upper Pennsylvanian beds were first placed in a single division, called Monongahela (Rogers, 1840) in the Appalachian region and Missouri (Keyes, 1893) in the Mid-Continent. Subsequent studies have led to partition in each of these regions as already indicated, the lower part now being called Conemaugh (Platt, 1875) and the upper part Virgil series (Moore, 1931–1932), in the respective regions. Boundary between Missouri and Virgil series has been placed somewhat lower, and on more significant paleontologic and structural grounds, than the Conemaugh-Monongahela boundary. The latter was designed to segregate

[99] H. H. Bradfield, *op. cit.* (1935), p. 10.

[100] Maynard P. White, personal communication, 1936.

an upper coal-bearing section with the Pittsburgh coal at the base from a lower section lacking important coal deposits. The Missouri-Virgil section has the added advantage of greater completeness and profuse marine faunal content on which interregional correlations may be more firmly established. These Upper Pennsylvanian rocks of North America contain *Pecopteris* followed by *Odontopteris*, indicating close agreement with the flora of lower and upper Stephanian stage of the Upper Carboniferous series of Europe.

Many faunal changes are noted between the Des Moines and Missouri series,[101] such as the zone of *Chonetina* which suddenly replaces that of *Mesolobus; Triticites* which follows the extinction of the genus, *Fusulina*. Floral changes between these series appear to be somewhat less abrupt. Both the Missouri and Virgil series have many distinctive forms, but some overlapping of faunal zones occurs, such as the subzone of *Triticites cullomensis*.

Broad regional uplifts brought channelling and low-angle unconformities between rocks of Des Moines and Missouri age, but during and especially near the close of Late Pennsylvanian time pronounced orogenic activity took place in southern Oklahoma, southwestern Texas, and New Mexico; presumably also in some other areas where the record is less complete. This Late Pennsylvanian orogenic activity led to vertical uplift of as much as 15,000 feet in the Arbuckles; also extensive thrust folding and faulting took place in the Marathon Mountains. In the latter area, beds of Virgil age were involved in this extreme folding, but became buried soon thereafter by early Wolfcamp beds containing *Schwagerina, Pseudoschwagerina* and many other characteristic Permian fossils. Other major positive features remained relatively inactive after early Missouri time, and subsided more or less uniformly with their flanking areas to be covered by 1,000–2,000 feet or more of rocks of upper Missouri and Virgil age. Such features include the central Kansas uplift, and the Electra, Muenster, and Concho arches of north and central Texas. The stratigraphic relationships and petrology of the Upper Pennsylvanian rocks has been described in much detail in reports by the various geological surveys and others, two of the most recent and precise of the Mid-Continent region being by Condra and Reed[102] and Moore, Frye, and Jewett.[103]

### TYPE MISSOURI SERIES, VIRGIL SERIES AND CORRELATIVES

The type sections of these two series of the Mid-Continent region as established during the past 12 years are well suited to serve as a standard for the Upper Pennsylvanian of North America.

As now generally defined, the type section of the Missouri series includes about 500 feet of section between base of the Warrensburg channel sandstone

[101] R. C. Moore *et al., op. cit.* (1944), pp. 668–78 and Chart 6.

[102] G. E. Condra and E. C. Reed, "The Geological Section of Nebraska," *Nebraska Geol. Survey Bull. 14* (1943), pp. 1–82.

[103] Raymond C. Moore, John C. Frye, and John Mark Jewett, "Tabular Description of Outcropping Rocks in Kansas," *Kansas Geol. Survey Bull. 52*, Pt. 4 (1944), pp. 137–212.

of the Bourbon formation (or group) and base of the Tonganoxie sandstone of the Douglas group. The type area is the Missouri River Valley, northwestern Missouri, northeastern Kansas and southwestern Iowa. A much expanded section occurs in Ardmore basin where beds of undoubted Missouri age exceed 2,000 feet in thickness, or about 3,000 feet if full thickness of the Hoxbar is included. Slight revision of earlier maps and correlations of the Hoxbar have been made.[104] Opinions differ regarding the need of any boundary revisions if the Hoxbar is restricted to beds of Missouri age. To accomplish this purpose in north-central Texas, the long established Canyon-Cisco boundary remains unchanged, but the basal boundary of the Canyon must be lowered from a lithologic choice of local importance (base of Palo Pinto formation) to the regionally important unconformity between the Lone Camp and Whitt groups[105] where sudden change from Des Moines to Missouri faunules is noted. Careful use of the term *series*, instead of group, should avoid confusion as to intended meaning of the names Strawn, Canyon, and Cisco, and permit continued use of these provincial, half-century old names, but in the new sense of time-stratigraphic divisions correlative with the Des Moines, Missouri, and Virgil series, respectively.

Faunules above the base of the Trivoli sandstone in Illinois show abrupt change from Des Moines to Missouri faunal types, and upward revision of the Carbondale-McLeansboro boundary to this position has been recommended.[106] Fusulinids resembling those of upper Virgil are reported from central Illinois in beds superjacent to Missouri equivalents.[107]

The Conemaugh and Monongahela divisions of Pennsylvania have been variously classified as series, groups, or formations. Their combined thickness ranges from 800 to 1,200 feet in western Pennsylvania and eastern West Virginia. Separation on a series basis apparently requires lowering of the common boundary about 150 feet, to the base of the Morgantown sandstone, near the middle of the combined Conemaugh-Monongahela section. Stout[108] has reported that this sandstone and all higher Pennsylvanian beds of the eastern Ohio region are of fresh-water origin.

The type Virgil section of eastern Kansas includes three groups, the upper two being separable according to Moore, Elias, and Newell[109] into at least 30 cyclothems, each with several marine phases in normal development. Total thickness of about 1,000 feet in the type area is approximately the same as that

[104] C. W. Tomlinson, "Correction of Stratigraphy of Hoxbar Formation, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18 (1934), pp. 1083–85.

[105] M. G. Cheney, *op. cit.* (1940), pp. 87–92.

[106] C. O. Dunbar, Lloyd G. Henbest, and J. Marvin Weller, *op. cit.* (1942), pp. 30–31.

[107] *Ibid.*, p. 31.

[108] Wilbur Stout, "Pennsylvanian Cycles in Ohio," *Illinois State Geol. Survey Bull. 60* (1931), pp. 195–216.

[109] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *Kansas Geol. Survey Bull. 22* (1935), and Chart (1934).

for the Cisco series in north-central Texas, although the latter is reported by some geologists to lack uppermost Virgil equivalents.

The faunas of the Missouri and Virgil series in the Mid-Continent region show marked differences from each other in many respects, as for example, the *Paraschistoceras reticulatum* assemblage of the Canyon series and the *Uddenites schucherti* assemblage of the Cisco series.[110]

### PENNSYLVANIAN-PERMIAN BOUNDARY

Conclusions regarding proper position of the Pennsylvanian-Permian boundary as set out in report of the subcommittee on the Permian[111] were reaffirmed by the present subcommittee. Usage and physical data added during the past 5 years give more support than refutation to inclusion of the Wolfcamp series in the Permian system. Placement of the base of the Wolfcamp at the base of the Admire group in the northern Mid-Continent region and below Saddle Creek and upper Waldrip beds (Pueblo formation expanded) in north-central Texas still appears logical. The Permian *Callipteris* floral assemblage of the latter section follows a Pennsylvanian flora found in the Newcastle coal according to C. B. Read (1941).[112] Philip B. King[113] classifies the Gray limestone member, containing *Schwagerina* but not *Pseudoschwagerina*, as basal Wolfcamp. This member occurs above the extensive regional unconformity which forms a natural boundary between the Pennsylvanian and Permian systems.

[110] F. B. Plummer and Gayle Scott, *op. cit.* (1937), pp. 378–90.

[111] C. W. Tomlinson *et al.*, *op. cit.* (1940), pp. 351–54.

[112] See Philip B. King, "Permian of West Texas and Southeastern New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), p. 684.

[113] Philip B. King, *op. cit.*, Pl. 2.

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VOL. 29, NO. 2 (FEBRUARY, 1945), PP. 170-186, 3 FIGS, 1 PLATE.

# REVISION OF STRATIGRAPHY OF PART OF CRETACEOUS IN TYLER BASIN, NORTHEAST TEXAS[1]

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## ABSTRACT

The subsurface Lower Cretaceous (Comanche) of the East Texas basin is divided into formations by electric logs and microfossils. The Maness shale, post-Buda in age and highest known Comanche formation, is described. It occurs near the center of the basin and is unknown at the outcrop. Beneath it is the Buda limestone, which is thin or absent at the outcrop in northeast Texas, except at a few localities where it is present as outliers. A Buda outlier is described on the Hill-Johnson County line and another outlier in Denton County contains *Budaiceras* and other fossils so far known only from the Buda. The beveled top of the Comanche in this area constitutes a widespread unconformity, which is definite near the east, north, and west margins of this basin, but near the center of the basin the existence of an unconformity is unproved. The overlying basal Woodbine ("Dexter beds" of R. T. Hill) contains ammonites none of which is known in the Lower Cretaceous (Comanche).

## INTRODUCTION

Subsurface studies in the Tyler (East Texas) basin or embayment of northeast Texas for the past 7 years, supplemented by several weeks of critical study at the outcrops of the Upper and Lower Cretaceous formations in northeast and north-central Texas, have enabled the writers to construct a number of detailed sections from the outcrop southeastward and eastward across the basin to the Sabine uplift, east of the East Texas field. As a result of these sections and subsequent checking by paleontology they are able to show conclusively that the Buda limestone and a hitherto unnamed overlying Lower Cretaceous shale are present in the subsurface of the Tyler basin below the Woodbine.[3] In previous papers on the subsurface of East Texas the Buda was either erroneously identified as Georgetown or was not separated from the rest of the Washita; the overlying shale was either called Grayson or merely Washita. (See Plate 1 for stratigraphic divisions.) This discovery was first made in October, 1940, but was not checked by paleontology until 1942.

The purposes of the present paper are (1) to point out the correct subsurface correlations and stratigraphic subdivisions, especially of the Washita and Fredericksburg groups; (2) to name and define the Lower Cretaceous (Comanche) shale, the Maness shale, which is not known at the surface and requires a subsurface type locality; (3) to state at what places on the outcrop unconformity has been demonstrated between the Woodbine and the underlying Lower Cretaceous

[1] Manuscript received, November 25, 1944.

[2] Geologists, Shell Oil Company, Incorporated. The writers gratefully acknowledge assistance from several geologists and stratigraphers, particularly paleontologic assistance in the subsurface by Frank E. Lozo and W. M. Furnish. They also thank the management of the Shell Oil Company, Incorporated, for permission to publish this paper.

[3] The ammonites and other fossils mentioned in the upper part of the Woodbine demonstrate conclusively that the upper part of the Woodbine is Upper Cretaceous (Gulf) in age. The fauna of the siltstones and sandstones at the base of the Woodbine is not sufficiently well preserved or has not been studied enough to ascertain whether it is also Upper Cretaceous or uppermost Lower Cretaceous (Comanche) but to date no restricted Lower Cretaceous species have been found in the Woodbine.

beds, and to indicate the present state of knowledge concerning this contact; (4) to present subsurface evidence for a regional unconformity between the Woodbine and the underlying Lower Cretaceous Washita group except, possibly, at the center on the East Texas basin. The paleontologic evidence which confirms the conclusions of the age of the Maness will be the subject of a forthcoming paper by Frank E. Lozo.

## STRATIGRAPHY

*General statement.*—The Cretaceous stratigraphy of this part of Texas and vicinity has been the subject of a large number of published reports and papers some of which are comprehensive. Adkins[4] has already compiled a bibliography and reviewed the history of the nomenclature, the type localities, and the correlation of the various stratigraphic divisions of the Cretaceous as well as their lithology, paleontology, *et cetera*, and the reader is referred to his work for a more complete general discussion. The present paper is written to record the new information in concise form so that it will be easily available to geologists, and not to review the voluminous literature on the Cretaceous. The part of the Cretaceous with which the present paper is mainly concerned is the upper part of the Lower Cretaceous and the overlying lower part of the Woodbine, the exact age of which is still undetermined. The sequence of stratigraphic units or formations which comprise this part of the Cretaceous together with the general lithology and electrical-log characteristics are shown on the correlation section across northeast Texas (Pl. 1) and are not described in detail. Within the last year or so several wells have been drilled through the Washita-Fredericksburg between the wells which appear on the section and the information from them strengthens the correlations indicated. The thicknesses of the various formations are shown graphically in Figure 1. Incidentally, this section gives an idea of the structure at the beginning of Woodbine deposition.

### FREDERICKSBURG GROUP

The Fredericksburg consists of three lithologic units, the Walnut, Goodland, and Kiamichi formations. The Walnut rests on the Paluxy (upper Trinity) green, gray, and red mudstones, and whitish, or greenish, more or less carbonaceous sandstones and siltstones.

*Walnut formation.*—This is generally a thin dark gray marl interbedded with gray shelly limestones. It is missing as a recognizable lithologic unit locally but is generally present and seems to be conformable or nearly so with the underlying Paluxy. Locally, the Walnut may grade into solid limestone, becoming practically inseparable from the Goodland limestone above.

*Goodland limestone.*—This consists mainly of hard, white to light grayish brown, dense-textured limestone commonly containing pelecypod fragments and

[4] W. S. Adkins, "The Mesozoic Systems in Texas," Vol. 1, Pt. 2, "The Geology of Texas," *Univ. Texas Bull. 3232* (1933), pp. 259–517.

veinlets of calcite. It varies in thickness from less than 50 feet to 250 feet or more but it is continuous and easy to recognize on electrical logs, because of its commonly high electrical resistivity.

*Kiamichi formation.*—The Kiamichi is characterized by laminated black shale but commonly contains thin beds of fossiliferous limestone, or *Gryphaea* beds. Owing to a variation in the determination of the top of Fredericksburg which is also top of Kiamichi, a zone of alternating limestone and dark shale above the main Kiamichi shale is shown on the correlation section as "Duck Creek or Kiamichi." The top of the Kiamichi is probably at the base of this unit and is shown by a heavy line on the correlation section.

### WASHITA GROUP

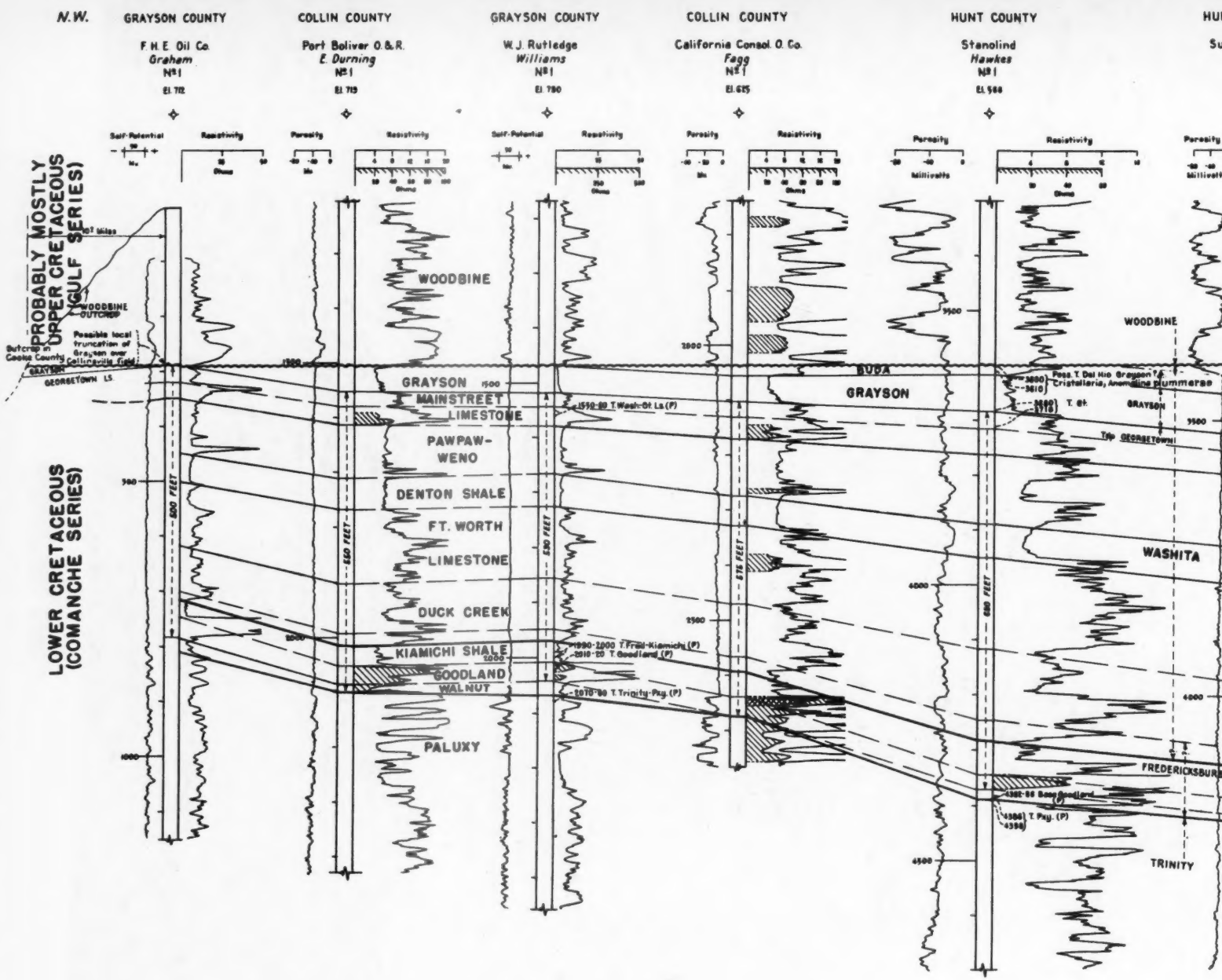
This group of limestones, marls, and shales rests conformably on the Fredericksburg. It is overlain by Woodbine with gentle angular unconformity in most of northeast Texas. However, on the west flank of the Sabine uplift (east flank of the Tyler basin), first the Eagle Ford and then the Woodbine are progressively truncated from west to east and are overlain with marked angular unconformity by the basal (Ector) member of the Austin chalk. The wedge edge of the Woodbine sand with its impervious cap of Ector chalk constitutes the trap for oil in the great East Texas field. This has been discussed by Minor and Hanna,[5] and other geologists.

The Washita is divided into eight stratigraphic units which can be readily traced in the subsurface (Pl. 1). Except for the Maness shale which is not known at the outcrop and the Buda which has been found at the surface only as far north as southern Denton County, the outcrop belts of each of these units in northeast Texas are readily mappable and contain more or less characteristic zone fossils. Therefore, each is given formational rank, following Adkins[6] and others.

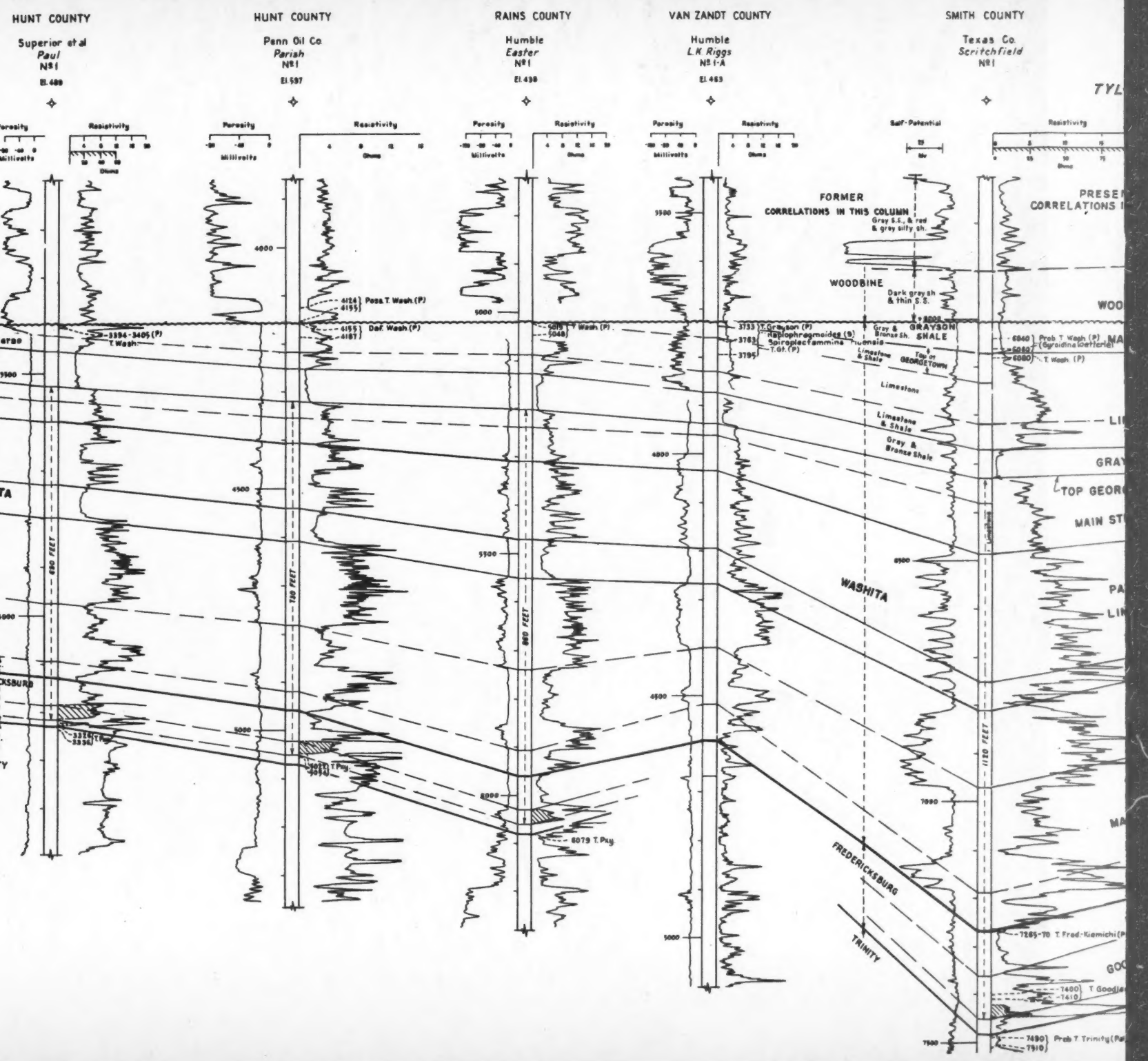
The lower five units are commonly lumped into the Georgetown, which is here recognized as a sub-group. In central Texas where it is only 60–100 feet thick and where most of the marls which separate the interval into mappable units are missing, so that it consists almost entirely of similar limestone, it becomes an undifferentiated sub-group or formation and is called the Georgetown limestone. In northeast Texas the top of the Main Street limestone is generally accepted as the top of the Georgetown sub-group and is so recognized by the writers. The Grayson (Del Rio) marl and Buda limestones are recognized and mapped as separate formations overlying the Georgetown in central and southwest Texas. They, together with the Maness shale, constitute an upper Washita sub-group which has not been named. The approximate subsurface distribution of the Maness shale is indicated by a dashed line on the index map (Fig. 1). The Washita limestones

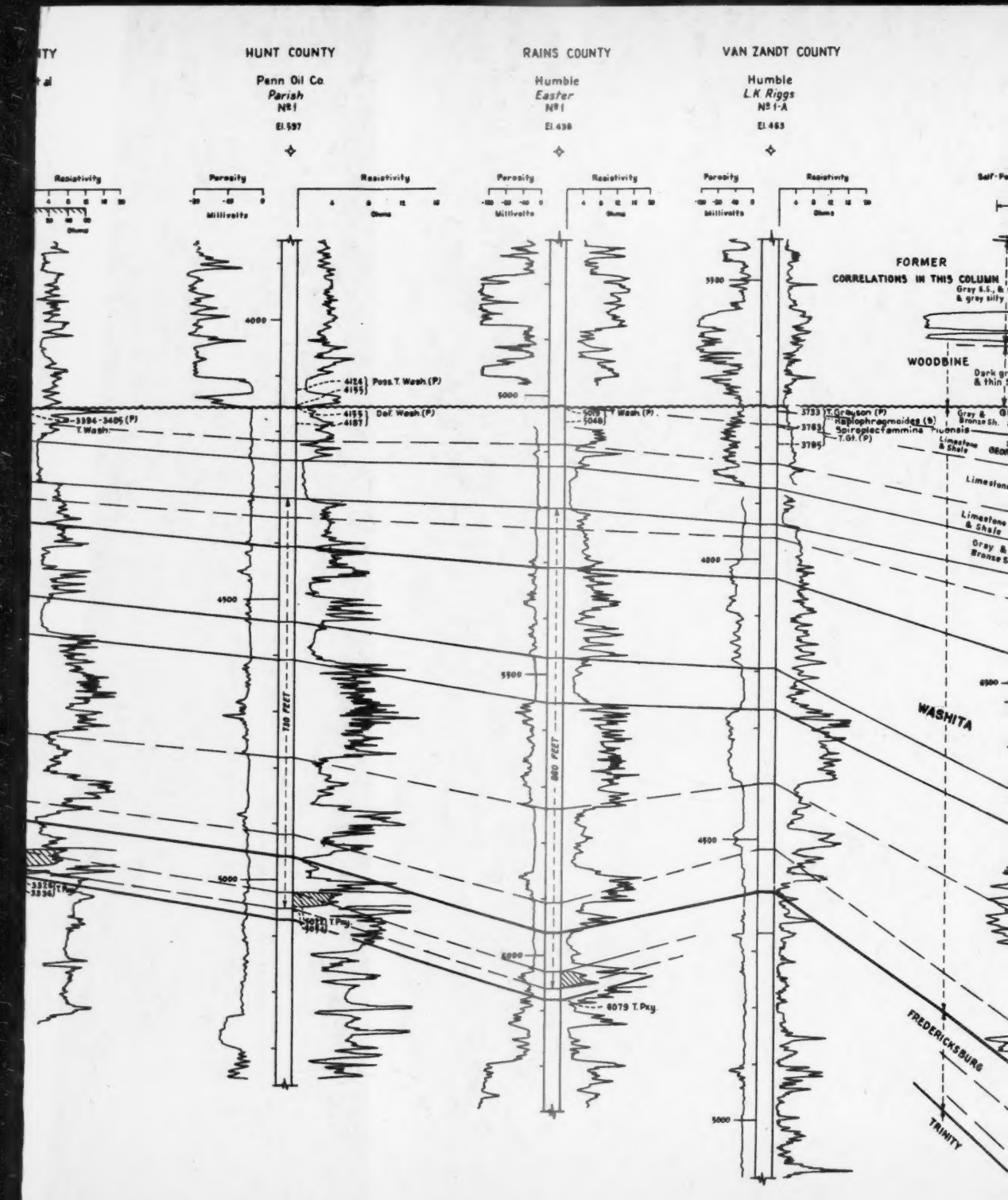
[5] H. E. Minor and Marcus A. Hanna, "East Texas Oil Field, Rusk, Cherokee, Smith, Gregg, and Upshur Counties, Texas," *Stratigraphic Type Oil Fields*, Amer. Assoc. Petrol. Geol. (1941), pp. 600–40.

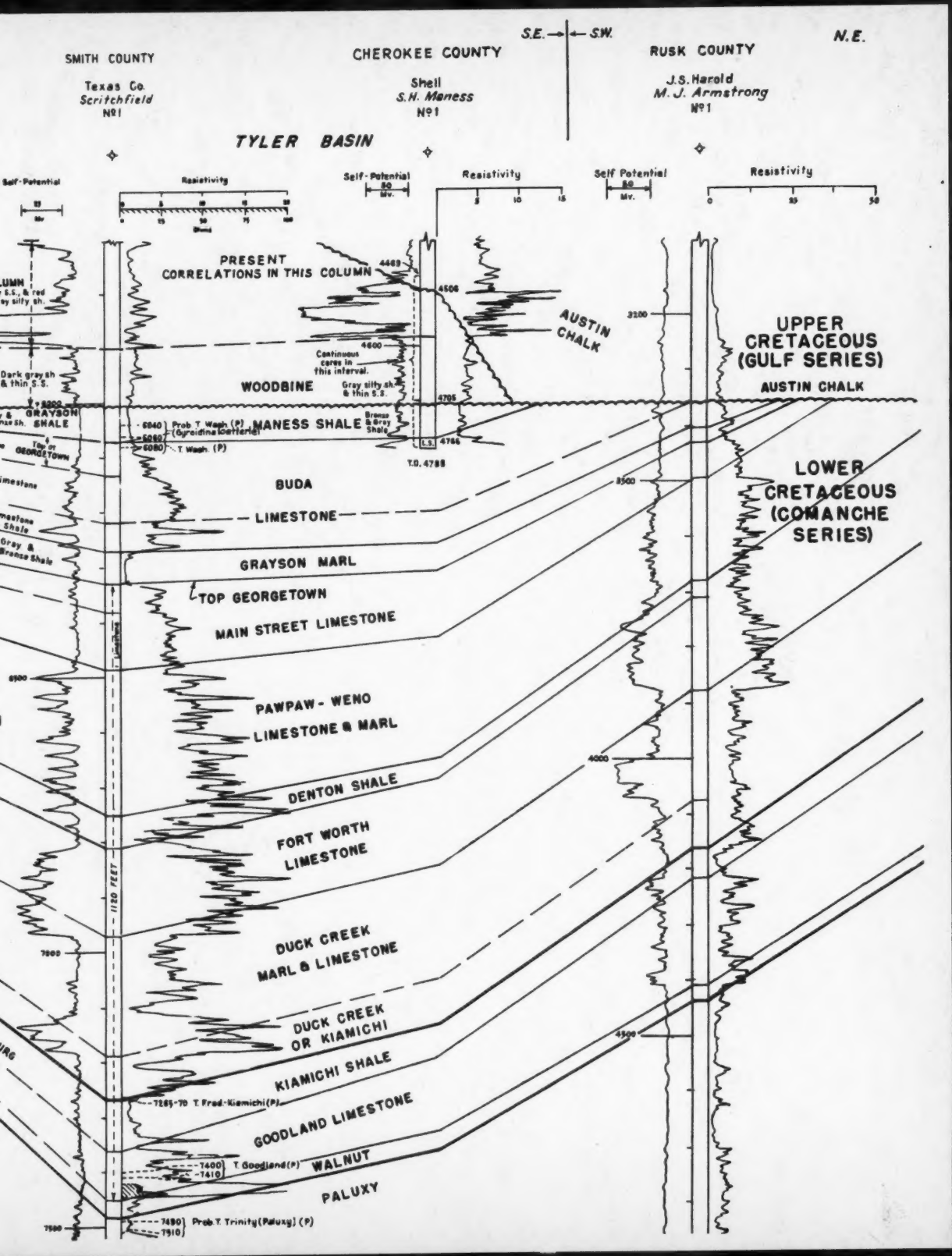
[6] W. S. Adkins, *op. cit.* (1933), pp. 359–400.




PL. 1.—Regional cross section correlated on base of Upper Cretaceous, showing angular unconformity at base of Upper Cretaceous and presence of Buda limestone and Maness shale in subsurface of Tyler basin, Rusk County to Cooke County, Texas. For location of section, see Figure 1. P = Paleontologic determinations (prior to October, 1940). Buda limestone and Maness shale are now recognized by several paleontologists and stratigraphers.


HUNT COUNTY
Superior et al
Paul
No 1
El. 489
HUNT COUNTY
Penn Oil Co.
Parish
No 1
El. 587
RAINS COUNTY
Humble
Easter
No 1
El. 438
VAN ZANDT COUNTY
Humble
L.K. Riggs
No 1-A
El. 463
SMITH COUNTY
Texas Co.
Scritchfield
No 1
TYL
Porosity
Resistivity
Self-Potential
Millivolts
Ohms
FORMER
CORRELATIONS IN THIS COLUMN
PRESE
CORRELATIONS I
Gray S.S., & red & gray silty sh.
WOODBINE
Dark gray sh & thin S.S.
WOO
GRAYSON
SHALE
Gray & Brown sh.
Limestone & Shale
Limestone
Limestone & Shale
Gray & Brown Shale
Taylor or GEORGETOWN
WASHITA
FREDERICKSBURG
TRINITY
GRAY
TOP GEOR
MAIN ST
LI
PA
MA
GOO
650 FEET
730 FEET
860 FEET
1180 FEET
3394-3405 (P)
T. Wash.
4124
4155
Poss. T. Wash. (P)
Def. Wash (P)
4187
5018
5048
T. Wash (P)
3793 T. Grayson (P)
3783 Haplophragmoides (?)
Spiroplectammina
3795 T. Gf. (P)
Fusulinella
6079 T. Pay
6940 Prob. T. Wash (P)
(Gyroidina beccariei)
6980
6990 T. Wash (P)
7285-70 T. Fred.-Kiamichi (P
7400
7410 T. Goodla
7490
7510 Prob. T. Trinity (Pa
4000
4500
5000
5500
6000
6500
7000
7500


HUNT COUNTY
Penn Oil Co.
Parish
No. 1
El. 597
RAINS COUNTY
Humble
Easter
No. 1
El. 438
VAN ZANDT COUNTY
Humble
L.K. Riggs
No. 1-A
El. 463
Resistivity
Porosity
Millivolts
Ohms
FORMER
CORRELATIONS IN THIS COLUMN
WOODBINE
WASHITA
FREDERICKSBURG
TRINITY
Limestone & Shale
Limestone
Gray & Bronze Sh.
T. Grayson (P)
Haplophragmoides (?)
Spiroplectammina
T. Gl. (P)
Poss. T. Wash. (P)
Def. Wash (P)
T. Wash (P)
T. Pky.
6079 T. Pky.
100 FEET
200 FEET
4000
4500
5000
5500
6000


S.E.
S.W.
N.E.
SMITH COUNTY
Texas Co.
Scritchfield
No 1
CHEROKEE COUNTY
Shell
S.H. Maness
No 1
RUSK COUNTY
J.S. Harold
M.J. Armstrong
No 1
TYLER BASIN
Self-Potential
Resistivity
PRESENT CORRELATIONS IN THIS COLUMN
AUSTIN CHALK
UPPER CRETACEOUS (GULF SERIES)
WOODBINE
Continuous cores in this interval.
Gray silty sh. & thin S.S.
GRAYSON SHALE
MANESS SHALE
Brown & Gray Shale
Prob. T. Wash. (P) (Cyroidina Lorterieri)
T. Wash. (P)
T.D. 4788
BUDA LIMESTONE
LOWER CRETACEOUS (COMANCHE SERIES)
GRAYSON MARL
TOP GEORGETOWN
MAIN STREET LIMESTONE
PAWPAW - WENO LIMESTONE & MARL
DENTON SHALE
FORT WORTH LIMESTONE
DUCK CREEK MARL & LIMESTONE
DUCK CREEK OR KIAMICHI
KIAMICHI SHALE
7285-70 T. Fred.-Kiamichi (P)
GOODLAND LIMESTONE
7400 T. Goodland (P)
7410
WALNUT
PALUXY
7490 Prob. T. Trinity (Paluxy) (P)
7510
1120 FEET

generally contain tiny microspherules of crystalline calcite (commonly called "spherical bodies") especially below the Grayson.

*Duck Creek formation.*—This formation consists of (1) a lower gray limestone member with minor intercalations of dark gray marl (especially in the lower part which may possibly be of Fredericksburg age and is shown on the cross section as Duck Creek or Kiamichi); (2) an upper member of alternating somewhat nodular, gray fossiliferous limestone and darker gray marl.

*Fort Worth limestone.*—This is a fairly hard, rather dense white to light gray limestone with minor streaks of gray marly limestone. In the central, eastern, southern, and southwestern part of the East Texas basin it is fairly porous. It is remarkably persistent as the most consistently pure limestone in the Georgetown sub-group and generally constitutes an easily recognized characteristic unit on electrical logs.

*Denton shale.*—At the outcrop north of Bell County and in the subsurface northwest of a line connecting central Bowie, southern Morris, the southwest corner of Smith, and the south corner of Limestone County the Denton consists largely of gray shale and marl. Southeastward from this line the shale becomes progressively thinner and contains limestone interbeds as shown by the cross section.

*Weno and Pawpaw formations.*—The Weno marl with interbedded, minor limestones and sandstones of the outcrop in Grayson, Cooke, and Denton counties, becomes progressively more calcareous downdip and consists largely of gray limestone with subordinate shale interbeds in the subsurface of the Tyler basin. The Pawpaw sand and shale of the outcrop in the aforementioned counties become progressively more shaly and then calcareous eastward and southward but thin calcareous sandstones are reported in some wells in this part of the Washita, particularly in the northern and northwestern parts of the Tyler basin. In much of the subsurface the Pawpaw is lithologically so similar to the underlying Weno that no attempt has been made to separate them (Pl. 1).

*Main Street limestone.*—This is a light gray or whitish fossiliferous limestone which thickens considerably and becomes less well indurated and more marly downdip. Its contact with the underlying Weno-Pawpaw is indefinite where the latter becomes calcareous and is recognized from the electrical logs; the Main Street generally shows less resistivity than the underlying limestones downdip from a line connecting Limestone, Hunt, and Red River counties.

*Grayson marl.*—Both at the outcrop and in the subsurface the Grayson (Del Rio) consists of light to dark gray marls and minor thin marly limestones. In a few wells in the deeper part of the Tyler basin, for example, The Texas Company's Scritchfield No. 1, the cuttings suggest that parts of the Grayson have a bronze or coppery tinge like the younger Maness shale, which has been confused with the Grayson in the past. The Grayson is generally fossiliferous, particularly at the outcrop, being characterized by an abundance of the ram's horn oyster, *Exogyra*

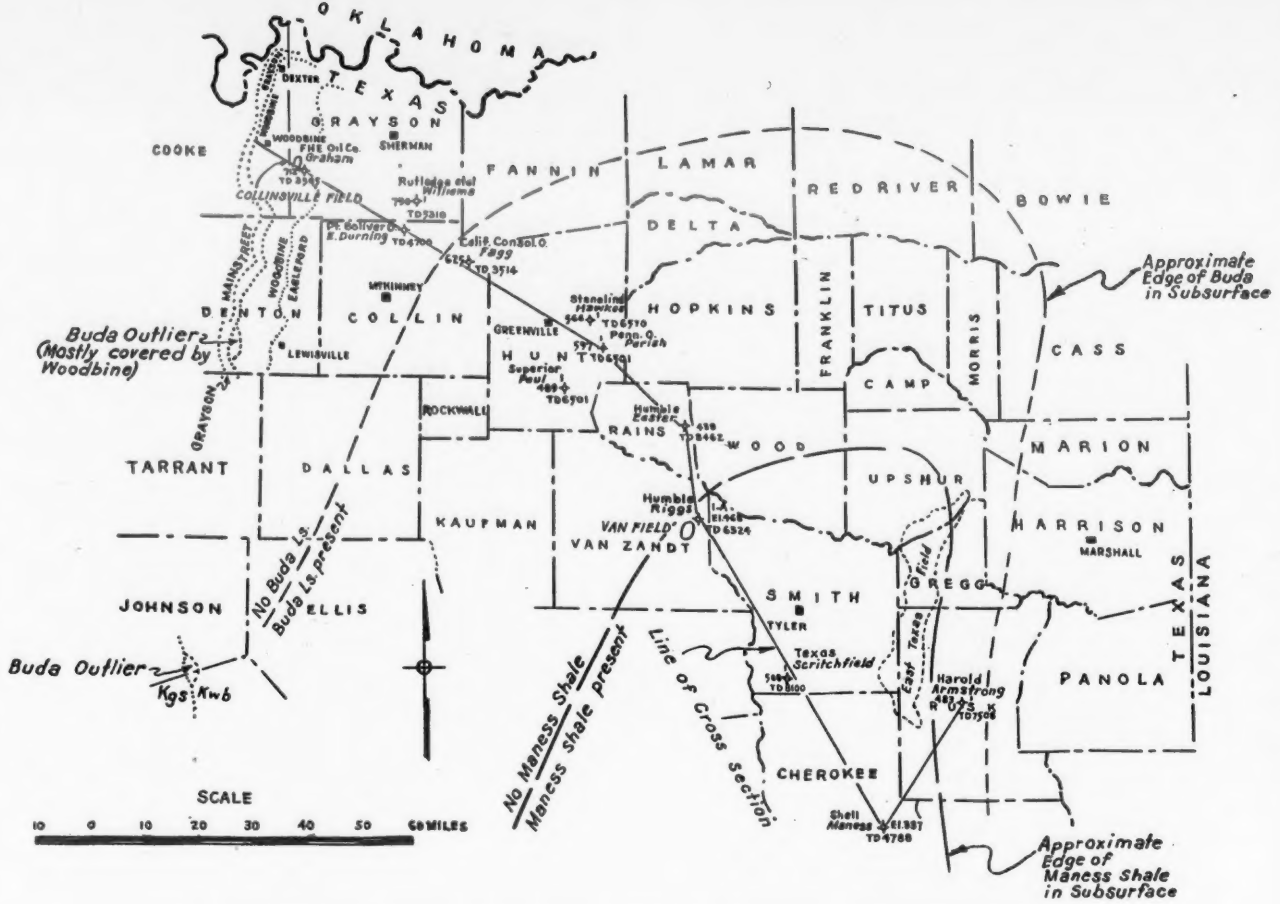



FIG. 1.—Index map showing location of cross section of Plate 1 and distribution of Maness shale and Buda limestone.

*arietina* Roemer; it generally contains a good foraminiferal fauna. It is commonly more calcareous near the top and is overlain by the Buda limestone; it also becomes more calcareous and thinner eastward and northward from the center of the basin.

*Buda limestone.*—At the outcrop (the continuous outcrop extends from near Waco southwest to the Rio Grande in Val Verde County) the Buda is mainly white, dense to porous sparsely to highly fossiliferous limestone. In the subsurface it is commonly a fairly hard, white, dense to porous, sparsely fossiliferous limestone. In many places it contains patches of glauconite grains. Where the entire thickness is present (in the central part of the Tyler basin) the upper part of the Buda becomes more marly and appears to grade upward into the Maness shale. The Buda of the subsurface has been confused with the upper Georgetown (Main Street) limestone and is still reported as Georgetown by some geologists and stratigraphers as well as by many production men and scouts. The first limestone below the Woodbine in most of northeast Texas is Buda rather than Georgetown. East of a nearly north-south line extending from Bowie to Nacogdoches County and north and west of a curving line passing from Red River County to Dallas County and thence south to the north end of the continuous Buda outcrop near Salado, Bell County, the Buda is entirely absent, presumably by truncation. The approximate subsurface distribution of Buda is shown on the index map (Fig. 1); the outer dashed line on this map gives the approximate subcrop (pre-Upper Cretaceous "outcrop") of the base of Buda. West of this line three or more outliers of Buda are known; two of them are shown on Figure 1: (a) just south of the Hill-Johnson County line; and (b) at and near Grayson Bluff, 3.7 miles N. 51° E. of Roanoke, Denton County, where W. S. Adkins and F. E. Lozo in September, 1944, collected *Budaiceras*, *Exogyra clarki* Shattuck, and other pelecypods, supposedly restricted to the Buda limestone. Another well known Buda outlier is at Bosqueville, McLennan County, and several occur in Bell County. At a locality (De-13) 4.8 miles N. 77° E. of Roanoke, Stephenson[7] recorded from a limestone of Buda-like lithology *Budaiceras* (two species) and various pelecypods, fossils hitherto reported only from the Buda.

The thickest, and possibly complete, section of Buda, is present only in those wells which lie in the deeper part of the Tyler basin, inside the main dashed line on Figure 1, which indicates the subcrop of the base of the Maness (top of Buda). The age of the lower Woodbine beds, which overlie the truncated Buda, is discussed later in this paper.

Taff[8] believed that the upper nodular member of the Grayson is Buda but produced no fossil evidence; the notion that this portion is lithologically similar to the Buda is incorrect. His typical locality for his North Texas "Buda" was the M. K. & T. Ry. crossing of the Elm Fork of Trinity River (north end of Lake

[7] L. W. Stephenson, "Fossils from Limestone of Buda Age in Denton County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 28, No. 10 (October, 1944), pp. 1538–39.

[8] J. A. Taff, "Report on the Cretaceous Area North of the Colorado River," *Texas Geol. Survey 4th Ann. Rept.* (1893), pp. 277, 280.

Dallas), now overwashed by alluvium. Correlations of various parts of upper Grayson and the Modlin Cemetery limestone (probably lower Buda) with the Buda have been made by Winton,[9] Scott,[10] Hill,[11] Alexander,[12] and perhaps others.

*Maness shale.*—This new formation is named from the Shell Oil Company's Maness well No. 1, eastern Cherokee County, in which the basal Austin, entire Woodbine, entire Maness and upper 12 feet of Buda limestone were cored continuously and in which the core recovery was excellent (more than 90 per cent). As the core recovery in the Maness shale (depths 4,705 feet to 4,766 feet) was nearly perfect, the writers hereby designate this cored section between the base of Woodbine and top of Buda as the type locality of the Maness formation. This is the so-called "bronze shale" of the East Texas field.[13] It is the youngest definitely known Lower Cretaceous (Comanche) in the Texas Gulf region and probably in the United States. The Maness shale has not been found at the surface and probably does not crop out. The possibility that Maness is represented in the basal Woodbine at the surface in northeast Texas is neither proved nor disproved paleontologically; at any rate, the Maness fauna has so far been found nowhere at the outcrop. The relations shown in Plate 1 indicate that the Maness does not reach the outcrop in northeast Texas. If the Maness equivalent is present in West Texas it is apparently not in a shale facies.

The maximum thickness of Maness shale found to date, 85 or 90 feet, was encountered in the Magnolia Petroleum Company's Braly No. 1, located in northern Cherokee County, 10½ miles southeast of The Texas Company's Scritchfield No. 1, and 3½ miles northeast of the line of cross section (Fig. 1). The Maness is 70–75 feet thick in wells in eastern Henderson and northern Houston counties and in the Long Lake field of southwestern Anderson County.

At the type locality in the Shell Oil Company's Maness No. 1 the Maness shale consists of faintly laminated to massive, bronze or copper-colored and dark gray, somewhat calcareous clay shale and claystone. In some parts there is a faint mottling of the gray and bronze colors. This shale is purer or less silty than the overlying dark gray silty shale, which contains lamellae and thin beds of hard, fine-grained, calcareous silty sandstone, and are shown as Woodbine on the cross section in Plate 1. These types of rock are lacking in the Maness formation and

[9] W. M. Winton, "The Geology of Denton County," *Univ. Texas Bull. 2544* (1925), p. 30.

[10] Gayle Scott, "The Woodbine Sand of Texas Interpreted as a Regressive Phenomenon," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), p. 615. Winton and Scott, "The Geology of Johnson County," *Univ. Texas Bull. 2229* (1922), p. 31.

[11] R. T. Hill, "Further Contributions to the Knowledge of the Cretaceous of Texas and Northern Mexico" (abstract), *Bull. Geol. Soc. America*, Vol. 34 (1923), pp. 72–73.

[12] C. I. Alexander, "Ostracoda of the Cretaceous of North Texas," *Univ. Texas Bull. 2907* (1929), p. 32.

[13] The "bronze shale" was noted in Kelsey dome by Denison, Oldham, and Kisling, "Structure and Stratigraphy of the Kelsey Anticline, Upshur County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 6 (1933), pp. 656–79.

no bronze color has been noted in the overlying shales (probably Woodbine) although maroon mudstones are common higher in the Woodbine. In this well the Maness contains a few small, smooth, thin-shelled *Pecten* and Foraminifera. Except for a few long range species, such as *Globigerina* cf. *cretacea* and *Ammobaculites* sp., only two species of possibly more restricted though unknown range, *Epistomina* sp. and *Bigenerina* n. sp., have been found in the post-Maness shale and sandstone (described in the following section) in the Shell's Maness No. 1. The two last-mentioned species are rather rare and might be reworked. However, it is possible that in the central part of the Tyler basin the unconformity between the Maness and Woodbine is largely filled in by nearly continuous sedimentation and that the beds called post-Maness below fill in much of the gap. There is still a faunal break at the top of the Maness because most species in it are not found above the top of the Maness shale.

A description of the continuously cored section in the Shell's Maness No. 1, which includes the type section of this uppermost Comanche shale, is given here for a permanent record.

DESCRIPTION OF CORED SECTION IN SHELL OIL COMPANY'S MANESS NO. 1, CHEROKEE COUNTY, TEXAS

| *Depths of Cores (Feet)* | |
|---|---|
| | AUSTIN CHALK (top not cored) |
| 4,469–4,486 | Chalk, hard, dark gray, faintly laminated, marly. Contains *Inoceramus* sp. and small glauconite grains. Two streaks of purer whitish chalk 1–2 feet thick |
| –4,501 | Chalk, white, slightly sandy, somewhat glauconitic with a few dark gray marl streaks. One inch of greenish white bentonite and one inch of black sideritic, possibly cherty limestone at 4,486 |
| –4,506 | Chalk, irregularly laminated, white and gray, slightly sandy, with black shale partings and abundant phosphatic and sideritic pellets. Bottom 8 inches is fossiliferous, sandy and shaly chalk with common pebbles of shale and chalk. Contact was cored and is slightly irregular as well as sharp (upper part of Woodbine and all the Eagle Ford removed by angular unconformity here) |
| | WOODBINE SANDSTONE (thickness 199 feet) |
| –4,511 | Siltstone, whitish, friable, sandy, grading into gray massive mudstone with a few greenish and faint brownish red mottlings. Red mudstone cuttings between 4,503 and 4,511 |
| –4,516 | Sandstone, grayish white, hard to somewhat friable, fine to medium, clean; sand grains predominantly quartz, minor feldspar and pink chert. A streak of green and red mottled waxy, slicken-sided claystone, 4,514–4,515 |
| –4,526 | Sandstone, white to pale pinkish, slightly friable, clean, quartzose. Cemented with calcite |
| –4,530 | Sandstone, friable, laminated, gray with gray shale partings interbedded with shale, laminated, red and gray |
| –4,556 | Sandstone, friable, smoothly laminated, grayish white to pale pinkish, medium-grained, clean, composed mostly of quartz and subordinate chert grains. A hard, brownish black 6-inch sideritic concretion at 4,545 |
| –4,561 | Siltstone, dark purplish gray, sandy, alternating with sandstone, cross-laminated, whitish. Thin streaks of red and green claystone |
| –4,564 | Shale, well laminated, black, silty, micaceous, and lignitic with thin irregular lamellae of hard, gray, fine sandstone |
| –4,574 | Shale, laminated, black, silty, with abundant carbonized plant fragments and sandstone, very hard, whitish, medium to fine, quartzitic, containing abundant large lignitized plant fragments. Dark gray siltstone in lower 2 feet |
| –4,585 | Sandstone, moderately friable but well consolidated, whitish, non-calcareous, porous, medium-grained becoming fine and silty in lower 2 feet |

POST-MANESS SHALE AND SANDSTONE (probable lower Woodbine)

| | |
|---|---|
| −4,660 | Shale, laminated, black and gray, silty, micaceous, containing about 30 per cent of cross-laminated, gray, fine sandstone lamellae 1–3 centimeters thick. Plant impressions are common in dark shale |
| −4,669 | Sandstone, faintly laminated, gray, very silty |
| −4,682 | Siltstone, cross-laminated, gray, sandy, alternating with shale, darker gray, silty, non-calcareous |
| 4,696 | Sandstone, faintly laminated to massive, medium to dark gray, very fine and silty, non-calcareous |
| −4,705 | Sandstone, very fine and silty, non-calcareous, interlaminated with shale, dark gray, silty, non-calcareous. Contact with underlying Maness shale was cored; it is sharp but apparently smooth |

MANESS SHALE (thickness 61 feet)

| | |
|---|---|
| −4,732 | Top one foot is claystone, conchoidally fracturing, dark gray with coppery tinge, very slightly calcareous. Claystone or shale, poorly laminated, conchoidally fracturing, slightly calcareous, dark gray, comprises remainder of interval. Rare shell fragments (small pelecypods mainly) noted at 4,711 feet and below show nacreous luster. A few lamellae of gray shaly limestone at 4,723–4,724 |
| −4,766 | Shale, faintly laminated, coppery gray to bronze-colored, calcareous. Contains a few thin-shelled pelecypods and ostracodes and rare foraminifera. Small smooth *Pecten* at 4,732 |

BUDA LIMESTONE (base not cored or penetrated)

| | |
|---|---|
| −4,776 | Limestone, massive to faintly laminated, marly but indurated, dense |
| −4,780 | Limestone, rather hard, light gray, slightly marly, dense |
| −4,788 (T.D.) | Limestone, hard, white, finely crystalline, apparently non-porous. Dark gray marly limestone partings give it a distinct laminated and banded appearance |

According to W. M. Furnish (written communication), the Maness shale, containing definite Washita fossils in a strategically located core from the Magnolia's Anderson No. 1 (Robertson County), has been recognized as far southwest as western Robertson County. In the East Texas field and in The Texas Company's Scritchfield No. 1 (southwest Smith County) it consists mainly of bronze or copper-colored shale, which was generally mis-identified as Grayson prior to 1943, and is still being mis-identified by some geologists. In the South Groesbeck field of Limestone County, in western Robertson County, and in eastern Henderson County it is dark gray, calcaleous shale containing Washita foraminifera and ostracodes. In the Shell's Stephens No. 1 on the LaRue salt dome, eastern Henderson County, the Maness is gray shale containing a prolific foraminiferal fauna; F. E. Lozo[14] reports that in this well the Maness contains "a diagnostic foraminiferal assemblage."

## POST-COMANCHE—PRE-WOODBINE UNCONFORMITY

The correlation section (Pl. 1) appears to demonstrate clearly that a regional, gentle, angular unconformity (against which all of the Maness, part or all of the Buda, and the upper part of the Grayson are truncated by the overlying basal Woodbine in the marginal parts of the basin) is present in northeast Texas. On the west flank of the Tyler basin the average rate of truncation of the Lower Cretaceous (Washita) is only 2 feet per mile and it is therefore not surprising that the difference in dip between it and the overlying Woodbine is difficult to detect

[14] Written communication, December, 1942.

even in large exposures, thus accounting for the apparent concordance of the contact at many places.

At the outcrop in Grayson County, at the northwest end of the cross section shown in Plate 1, the top of the known Comanche in truncated and is overlain by the lower part of the zone which R. T. Hill loosely called Dexter beds (here called "lower Dexter").

*Outcrop in northeast Texas.*[15]—In northern Grayson and Cooke counties, Texas, the Woodbine has not been accurately zoned, and therefore to date no detailed partition is known. Electrical logs suggest that the Woodbine is too variable to zone consistently at least on a lithologic basis (Pl. 1). However, the following general subdivisions exist.

2. Lewisville (an upper division) whose base has not been clearly defined and not definitely traced beyond the Lewisville area, Denton County)

Marine clays and calcareous sandstones containing pelecypods, gastropods, and ammonites (*Acanthoceras* aff. *wintoni*, *Acanthoceras* aff. *tarrantense*, found near Lewisville)

1. "Dexter" (a lower division)
   - (c) "Upper Dexter": thin-bedded sandstones and arenaceous shales
   - (b) "Middle Dexter": massive sandstones
   - (a) "Lower Dexter" as exposed in the northeast branch of Rock Creek, 2 miles southwest of Dexter, Cooke County, Texas: sandstones, siltstones, and blue and black shales containing ammonites, pelecypods, and a sparse microfauna; about 50 feet of beds bounded above by the massive "Middle Dexter" sandstones and below by the Grayson

The "lower Dexter" overlies the Grayson or the Main Street, the highest Comanche level which has been identified to date in this area. No definite age identification exists for the "lower Dexter" to date. The ammonites recently collected from it by Adkins, Lowman, and Lozo have not been identified but appear to be different genera from known Washita ammonites. The basal part of the "lower Dexter" contains *Ammobaculites* cf. *subcretaceus*, *Textularia* sp. aff. *rioensis*, *Trochammina*, *Globigerina* cf. *cretacea*, minute *Gümbelina* sp., minute *Globigerina* sp., which occur in both Lower Cretaceous and Upper Cretaceous and do not indicate any precise age, and *Flabellammina denisonensis* Tappan.

*Buda.*—No outcrop Buda is known in Cooke and Grayson counties.

*Grayson.*—The Grayson where best developed consists of four parts.

- (d) Upper non-nodular marl (Gs-4). No restricted zone fossils yet determined. 0–13 feet thick
- (c) Nodular very marly limestone (Gs-3). 0–23 feet thick. Contains *Stoliczkaia* sp. (common), *Mantelliceras* n. sp. (rare), *Gryphaea* "*mucronata*" Gabb[16] (abundant), and widely ranging Grayson fossils: *Turrilites* sp. cf. *brazoensis* (small), *Engonoceras* sp., *et cetera*
- (b) Non-nodular marl (Gs-2). 10–38 feet. Contains *Exogyra arietina* Roemer (rare), *Gryphaea* "*mucronata*" (abundant)
- (a) Basalmost nodular marly limestone (Gs-1). 0–5 feet. Transitional to the underlying Main Street limestone. Contains abundant *Exogyra arietina*, but *Gryphaea* "*mucronata*" absent or rare and small

*Main Street* (5–40 feet thick).—This limestone forms a thin, continuous and identifiable outcrop marker throughout this area, and serves as control on the behavior of the overlying Grayson. It is recognizable by its content of *Exogyra*

[15] Much of the field work was done by W. S. Adkins, S. W. Lowman, and F. E. Lozo in 1944.

[16] A new species, which will be described.

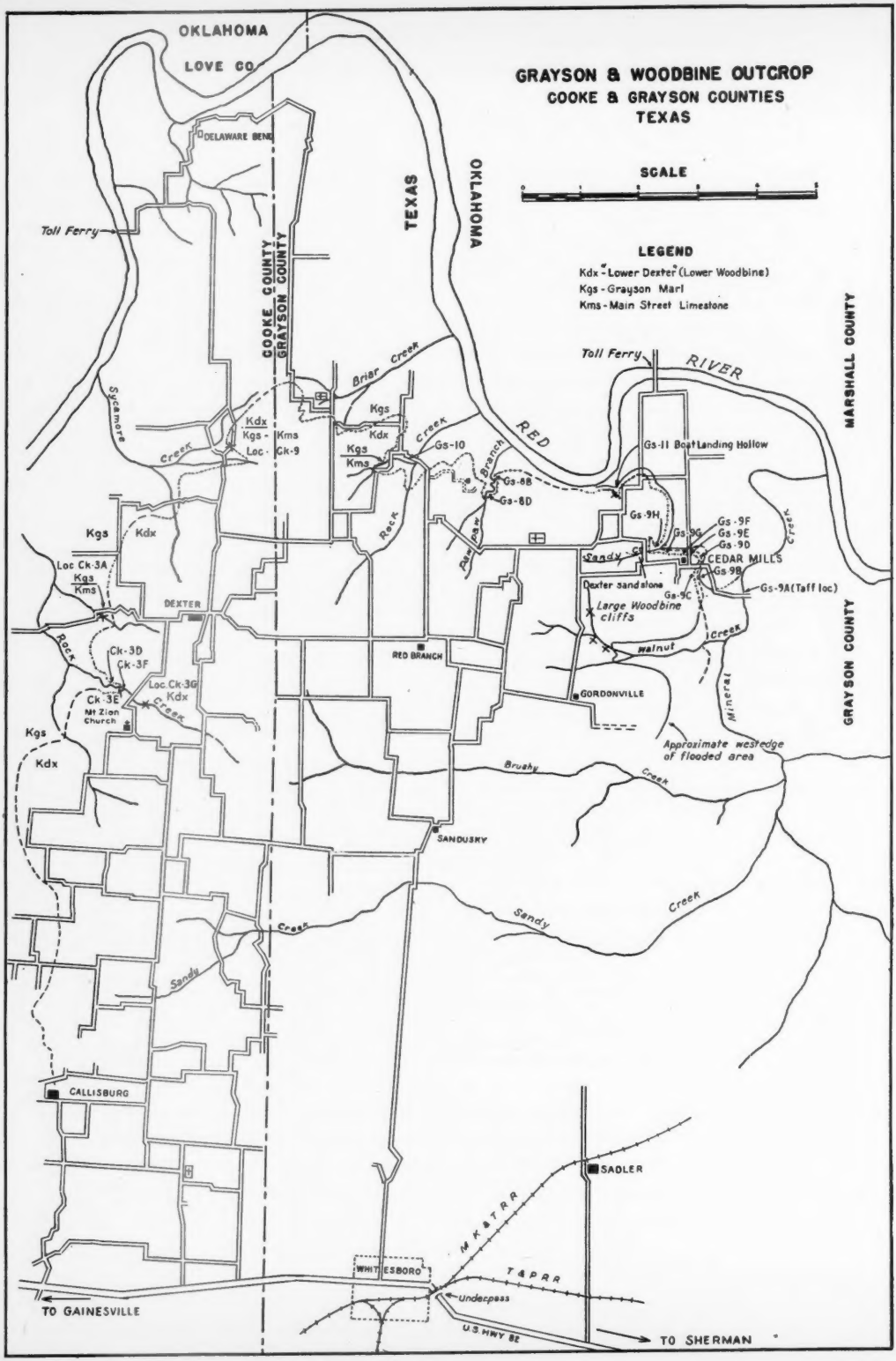



FIG. 2.—Map showing outcrop localities of Grayson-Woodbine contact in Grayson and Cooke counties, Texas.

*arietina* (abundant), *Lopha quadriplicata* (Shumard) (highest occurrence), *Kingena* (abundant), *Ptychomya ragsdalei* (Cragin), large typical *Turrilites brazoensis* Roemer, and locally *Gryphaea "mucronata."*

*Contact at top of Grayson* (Fig. 2).—The foregoing zonation given for the Grayson in this area permits ascertainment of the contact relations at the top of the Grayson. From Dexter (northeastern Cooke County) east to Pawpaw Creek (northwestern Grayson County) all four units are present, and the top one is overlain by "lower Dexter."[17] At Boat Landing Hollow only 5½ feet of basalmost Grayson (Gs-1) remains, containing *Pseudananchys supernus*, abundant *Exogyra arietina, et cetera*, and is overlain by "lower Dexter." At a locality ½ mile northwest of Cedar Mills, at the base of the "Lower Dexter" is a massive conglomerate containing apparently reworked Grayson fossils, which markedly truncates the basalmost Grayson (Gs-1) and at the east end of the exposure is in direct contact with Main Street limestone. In four localities immediately east and southeast of Cedar Mills only 3–7 feet of basalmost Grayson (Gs-1) remains above the Main Street limestone and below the "lower Dexter." At a locality, now inundated, reported by Taff 1 mile east of Cedar Mills, the ravined top of the Main Street limestone is directly overlain by Taff's "blue green clay (Dakota)," that is, the basal clay of the "lower Dexter." The relations at the outcrop on Cooke and Grayson counties are shown in Figures 2 and 3. The removal of some or all of the Grayson in this area adjacent to old uplifts (Preston anticline) is local, and farther south, in Denton County, the upper Washita section becomes more nearly complete.

At Grayson Bluff, 3.7 miles N. 51° E. of Roanoke, Denton County, the following section is present.

| | *Feet* |
|---|---|
| "Lower Dexter" brownish gray fine sandstone and black shales | 22 |
| Buda (Modlin Cemetery limestone), as exposed in Grayson Bluff, in the road cut ⅜ mile north of Grayson Bluff, at Modlin Cemetery, and elsewhere. Hard shelly limestone; contains *Budaiceras* (two species), *Exogyra clarki* Shattuck, and other fossils (*Trigonia et cetera*) as in the Buda in Bell County | 1–4 |
| Grayson (d) Non-nodular marl | 13 |
| (c) Nodular marly limestone | 22.8 |
| (b) Non-nodular marl | 37.4 |
| (a) Basalmost nodular marly limestone, transitional to Main Street limestone | 2+ |
| Main Street limestone | 10+ |

Other Buda localities are at points 3 miles east of Roanoke (0.45 mile east of Modlin Cemetery), and 4.8 miles N. 77° E. of Roanoke.

South of Grayson Bluff the next known Buda outcrop is just below the Johnson-Hill County line, 5 miles S. 65° E. of Rio Vista (2 miles southwest of Parker);[18] then at Bosqueville;[19] thence the outcrop has Buda intermittently present and

[17] At Pawpaw Branch (Gs-8) the basal black shale of the "lower Dexter" visibly truncates the underlying Grayson, as is shown in Figure 3.

[18] Discovered by W. S. Adkins, 1933.

[19] Adkins, *Univ. Texas Bull. 2340* (1924), pp. 58–67.

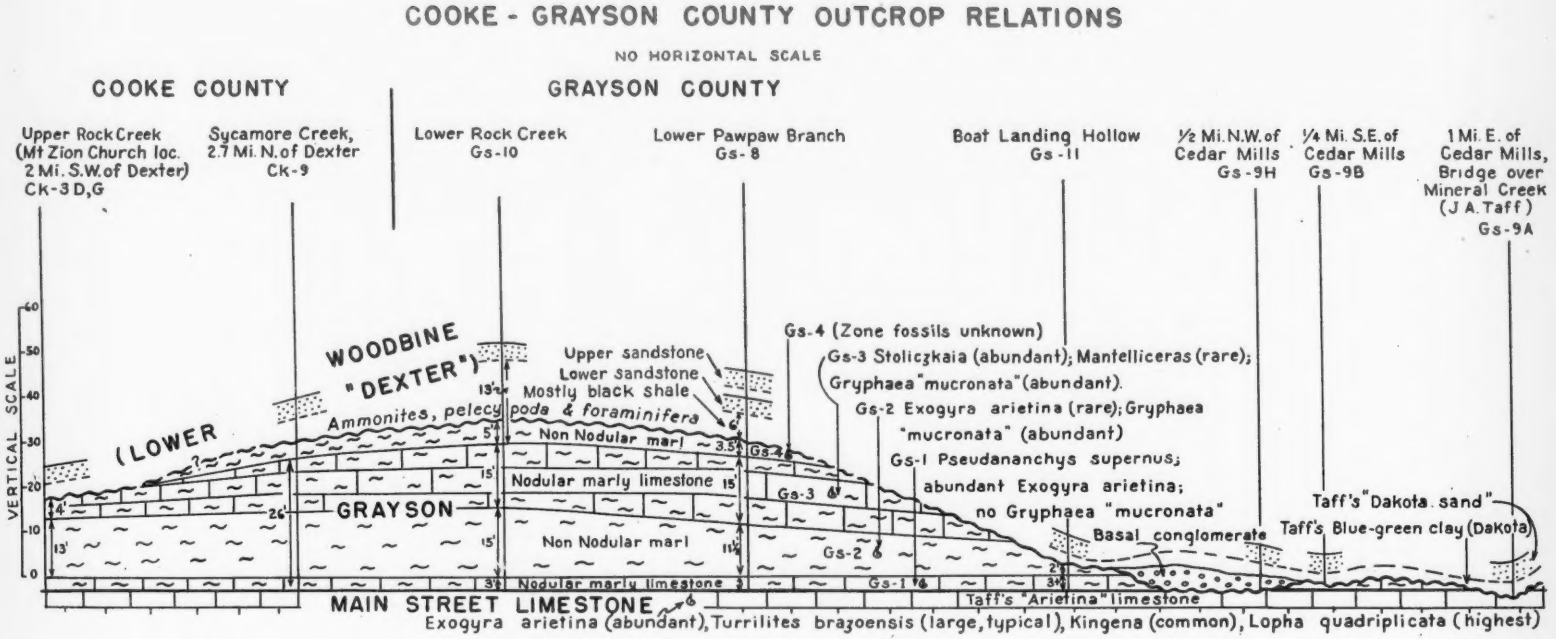

COOKE - GRAYSON COUNTY OUTCROP RELATIONS
NO HORIZONTAL SCALE
COOKE COUNTY
GRAYSON COUNTY
Upper Rock Creek (Mt Zion Church loc. 2 Mi. S.W. of Dexter) Ck-3 D,G
Sycamore Creek, 2.7 Mi. N. of Dexter Ck-9
Lower Rock Creek Gs-10
Lower Pawpaw Branch Gs-8
Boat Landing Hollow Gs-11
½ Mi. N.W. of Cedar Mills Gs-9H
¼ Mi. S.E. of Cedar Mills Gs-9B
1 Mi. E. of Cedar Mills, Bridge over Mineral Creek (J. A. Taff) Gs-9A
VERTICAL SCALE
WOODBINE ("DEXTER")
(LOWER
GRAYSON
Ammonites, pelecypoda & foraminifera
Upper sandstone
Lower sandstone
Mostly black shale
Non Nodular marl
Nodular marly limestone
Non Nodular marl
Nodular marly limestone
MAIN STREET LIMESTONE
Exogyra arietina (abundant), Turrilites brazoensis (large, typical), Kingena (common), Lopha quadriplicata (highest)
Gs-4 (Zone fossils unknown)
Gs-3 Stoliczkaia (abundant); Mantelliceras (rare); Gryphaea "mucronata" (abundant).
Gs-2 Exogyra arietina (rare); Gryphaea "mucronata" (abundant)
Gs-1 Pseudananchys supernus; abundant Exogyra arietina; no Gryphaea "mucronata"
Basal conglomerate
Taff's "Arietina" limestone
Taff's "Dakota sand"
Taff's Blue-green clay (Dakota)

FIG. 3.—Sketch section showing stratigraphic relations of Woodbine to underlying Grayson and Main Street formations along outcrop in Cooke and Grayson counties, Texas.

absent southward to a point 3 miles east of Salado[20] where the main continuous body of the Buda outcrop begins. It is probable that the thinned Buda at Grayson Bluff and elsewhere represents basal Buda, since *Budaiceras* is more prevalent in lower Buda, whereas *Pecten roemeri* is more prevalent in upper Buda, and was not found in Denton County or vicinity.

On the slightly gullied floor of the sand pit 2.4 miles north of Dexter, Cooke County, is a good exposure of an irregular erosion surface with distinct channeling and 1–3 feet of black sandy clay (interpreted as fossil soil) at the base of Woodbine massive sandstone (top of Grayson) which corroborates the previous surface and subsurface evidence. As an unconformity has been reported by geologists at the base of the Upper Cretaceous in other parts of Texas as well as adjacent parts of Oklahoma and Arkansas, it is very probable that this unconformity is present throughout this region. In southwest Arkansas on the Oklahoma line near Cerrogordo, the Woodbine rests directly on the Fredericksburg (all the Washita group has been truncated) and farther east the Woodbine transgresses the outcrop of all the Fredericksburg and part of the Trinity. In view of the overwhelming evidence for a widespread unconformity at the base of the Woodbine, the presence of diagnostic Upper Cretaceous ammonites, gastropods, and pelecypods in the upper Woodbine (as originally defined by R. T. Hill),[21] southwest of the town of Lewisville in southern Denton County, and of a few fossils known from the lower Woodbine but unreported from the Comanche, the logical boundary between the Upper and Lower Cretaceous seems to be the base of the Woodbine "formation." On the west flank of the Tyler basin the angular difference in dip between the Washita and the overlying Woodbine is extremely small, only about 2 feet per mile, so that in most outcrops the unconformity appears to be merely disconformable or else concordant. On the east flank of the basin the difference in dip may be lightly greater; in Cherokee and Rusk counties the Buda dips about 3 or 4 feet per mile more steeply than the base of Woodbine. Also, on the east flank, the unconformity at the base of the Austin (within the lower part of the Upper Cretaceous) is much more angular than that at the base of Woodbine (top of Lower Cretaceous).

### WOODBINE GROUP

The Woodbine is considered to be an undifferentiated group at present instead of two formations as considered by some geologists because its lithologic units are so variable or local in geographic distribution, both along strike and up and down the dip, that it has not yet been successfully divided into consistent regional mappable units. In Texas it is composed mainly of (1) massive or cross-bedded, gray to whitish or pinkish, fine- to medium-grained, calcareous to non-calcareous, more or less carbonaceous, slightly feldspathic sandstones with minor lenses of coarse

[20] Adkins and Arick, *Univ. Texas Bull. 3016* (1930), pp. 48–59.

[21] R. T. Hill, "Geography and Geology of the Black and Grand Prairies, Texas," *U. S. Geol. Survey Ann. Rept. 21*, Pt. 7 (1901), p. 292.

pebbly sandstone; (2) red and green, commonly mottled mudstones and shales, many of which contain microconcretions (tiny spheroidal pellets) of brown ankerite or siderite; (3) light gray to whitish, laminated, sandy siltstone with lignitic partings and lenses; (4) laminated to fairly massive, dark gray, micaceous, carbonaceous silty shale containing thin lignite beds; and (5) dark green to greenish gray volcanic sandstones and pebbly sandstones (composed of quartz, feldspar, chert, waterworn grains of partly altered volcanic rocks and a few worn sericite-schist grains) which are commonly cemented with fibrous serpentine or with chlorite or a mixture of these green minerals and calcite. A few thin beds of light gray, fossiliferous, shaly to sandy limestone or extremely calcareous siltstone were cored in the middle part of the Woodbine (between 6,240 and 6,271 feet) in Hunt's Elliott No. 1, near Percilla, Houston County.

The dark gray to black shales in the Woodbine are commonly better developed near the top and base and locally contain brackish or marine pelecypods and gastropods. A few generalized types of arenaceous Foraminifera were found in outcrop samples of this fossiliferous shale. Some of the calcareous sandstones especially near the top (as near Lewisville, southeastern Denton County) are also fossiliferous.

The volcanic sandstones are best exposed in northern Lamar and Red River counties, Texas, and become progressively thinner and contain fewer volcanic grains west and southwest of Lamar County. They are excellently developed in wells in the Leesburg field of Camp County and in the Bass Drilling Company's Crichton well No. 1 near Minden in Webster Parish, northern Louisiana.

In the Van field Liddle[22] states that "a more or less arbitrary division separates the Woodbine at Van into an upper bentonitic and a lower non-bentonitic section." The bentonitic sands are described as quartz sands cemented by greenish gray or bluish gray bentonitic material.

At the outcrop in southwest Arkansas the Woodbine consists largely of volcanic sandstones and conglomerates (grains and pebbles are water worn); this volcanic facies has been called Centerpoint formation from the town of Centerpoint in Howard County by Hazzard,[23] who thinks it is Eagle Ford in age but correlates it with the Lewisville member of the upper Woodbine. Hazzard also thinks that the base of the "Lewisville" rests unconformably upon the "Dexter" member of the Woodbine. No sign of an unconformiy or even of a definite mappable contact within the Woodbine was found by the writers near Lewisville, although several thin conglomeratic beds are found within the upper part of the fossiliferous Lewisville member. As the same fauna is found above and below them as well as in the pebbly lenses themselves, the conglomerate zones in this vicinity do not

[22] R. A. Liddle, "The Van Oil Field, Van Zandt County, Texas," *Univ. Texas Bull. 3601* (1936), pp. 24–25.

[23] Roy T. Hazzard, "The Centerpoint Volcanics of Southwest Arkansas, a Facies of the Eagle Ford of Northeast Texas," *Shreveport Geol. Soc. Guide Book*, 14th Ann. Field Trip (1939), pp. 133–48.

indicate important unconformities but merely minor breaks in sedimentation which are common in the Woodbine.

Part of what has been called Woodbine in extreme northeastern Texas and southwestern Arkansas, where the Eagle Ford shale is mapped as thin or absent, may possibly be Eagle Ford in age (the Eagle Ford shale may grade into the upper part of the Centerpoint). On the other hand, this supposed absence of Eagle Ford shale can be just as logically explained by eastward truncation of the Eagle Ford by the overlying Tokio-Bonham shale and sandstone of the Austin group similar to that which occurs in the subsurface in the East Texas field. However, the log and sample descriptions from a well (J. B. White's Kurth Lumber Company No. 1) near Acworth, northern Red River County, Texas, suggests that the Eagle Ford shale here is included in the lower Bonham on the geologic map of Texas. Unfortunately, much of the critical area (near the junction of Texas, Oklahoma, and Arkansas) where the problem might be solved by careful following of several individual lithologic units) is covered with Quaternary deposits of the Red River, but additional field work may clarify the problem.

The Woodbine formation was originally named for the village of Woodbine, Cooke County, Texas, by R. T. Hill;[24] he called the fossiliferous beds in the upper part "Lewisville beds" from their excellent exposures on Timber Creek southwest of Lewisville, Denton County, and the lower generally unfossiliferous part of the Woodbine "Dexter beds," from the village of Dexter, located near the base of the Woodbine in extreme northeastern Cooke County. Hill mapped no contact between these two hazy divisions and the only criterion mentioned by which they might be recognized is the content of the marine fossils in the Lewisville beds. Subsequently, some geologists have attempted to place the base of the Lewisville member at the lowest occurrence of noticeable volcanic detritus in the Woodbine. However, the writers collected a sample of rusty, buff to greenish buff, cross-bedded sandstone[25] only $\frac{1}{4}$ mile south of Dexter at the type locality of Hill's lower "member."

This volcanic sandstone at Dexter, Cooke County, is interpreted as a stringer intercalated with the non-volcanic sandstones of the lower Woodbine and not

[24] R. T. Hill, *op. cit.*, p. 292.

[25] A thin section of this sandstone was studied under the petrographic microscope by Bailey. It contains about 4 per cent of water-worn, more or less serpentinized or chloritized grains of volcanic rock with a definite pilotaxitic (felty) texture. The volcanic grains are composed of tiny crystals of feldspar, magnetite, and an altered ferromagnesian mineral, possibly pyroxene. About 85 per cent of the sandstone consists of subrounded to subangular grains of quartz and 2 per cent or less of argillaceous material, chert, phyllite, feldspar, and biotite grains. The cementing material is mainly green chlorite and reddish brown, hydrous iron oxide; the cementing material was apparently derived from alteration of the ferromagnesian minerals which were apparently dissolved, dehydrated, and redeposited by ground water between the quartz and other grains of the rock. Probably a number of original igneous grains (now leached chloritic and argillaceous material) have altered too completely to be recognizable and have contributed much of the chlorite for the cement. However, not more than 5 or 6 per cent of the grains in this sandstone could have been volcanic rock fragments originally. Thin sections of similar rusty to greenish buff sandstones in the upper part of the Lewisville beds southwest of Lewisville showed a small percentage (about like that at Dexter) of rounded much altered or leached (hence doubtful) volcanic grains.

correlatable with the lowest volcanic sandstone found near Lewisville, Denton County, where it is in the upper third of the Woodbine, but detailed mapping requiring auger holes to trace units definitely is necessary actually to prove whether or not this interpretation is correct.

As most of the Woodbine in the Lewisville fossiliferous zone contains no suggestion of volcanic grains, the only distinction left is the presence of the fossils and these are rare in the lower part of the Lewisville zone.

The principal evidence against an Eagle Ford age of the Lewisville fossiliferous zone of the upper Woodbine is the fact that the Lewisville fauna at the type locality is distinct from that in the overlying fossiliferous Eagle Ford, although the two faunas are closely related. Previously unreported or described Woodbine ammonites (in heavy sandstone outcrops) were discovered by Stanley M. Morse[26] and the writers at three localities near Lewisville. Two of the localities are on the rocky banks of the south fork of Timber Creek (1) ¼ mile above (southwest of) its junction with the main stream, 3 miles S. 57° W. of the Lewisville water tower (soil map of Denton County used as base); (2) in hard, slabby, calcareous sandstone that forms a waterfall in the creek 3.6 miles S. 63° W. of Lewisville, ½ mile upstream (west) from locality 1 and 0.8 mile north and 0.2 mile east of Flower Mound country church. The third locality (3) is on the east bank of the main (north) fork of Timber Creek, 3 feet above water's edge (medium stage) and about 100 yards below the road bridge over the creek, 3 miles S. 78° W. of Lewisville. Two species are represented—a slender and a thicker one; Adkins found that these are respectively somewhat like *Acanthoceras wintoni* Adkins and *Acanthoceras tarrantense* Adkins of the basal Eagle Ford but different from those species. At locality 1 the ammonite is associated with *Turritella* sp., *Ostrea soleniscus* Meek, *Exogyra* cf. *ferox* Cragin, and *Crassatella?* sp.; *Ostrea soleniscus* is found near the ammonites at locality 3.

The writers believe that the Lewisville beds should remain in the Woodbine where they were originally placed and should not be correlated with the Eagle Ford for the following reasons.

1. The ammonites and associated mollusks of the Lewisville beds are different from the fauna in the Eagle Ford.

2. No well defined contact was found between the Lewisville and the rest of the Woodbine ("Dexter") below. Even if it should prove possible by very detailed work to map a contact at the base of the Lewisville this would not prove that the Lewisville is Eagle Ford in age.

3. In most wells in the Tyler basin the Woodbine is a sandy interval containing thick sandstones, green volcanic sandstones, red beds, and important lignite beds which are generally absent in the overlying predominantly black marine shale and minor thin flaggy sandstones of the Eagle Ford.

More work needs to be done to correlate definitely the Centerpoint formation of southwest Arkansas with the Woodbine of Texas, although such a correlation seems probable at the present time.

[26] Lieutenant Stanley M. Morse was killed in action in Italy on May 21, 1944.

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# THRUST FAULTING IN ARBUCKLE MOUNTAINS, OKLAHOMA[1]

ROY P. LEHMAN[2]
Shawnee, Oklahoma

## ABSTRACT

There are thirteen erratic masses superimposed on Simpson strata ranging in age from the Oil Creek formation to the Bromide formation south of the city of Sulphur, Murray County, Oklahoma. The rocks of the erratic masses range in age from the McLish formation to the Trenton formation. Their occurrence has not been previously recognized. The stratigraphy and structural history of the area and the possibilities of the origin of the erratic masses are discussed. It is concluded that these erratic masses are outliers of an overthrust sheet. The overthrust, from the southwest, occurred in post-Hoxbar-pre-Pontotoc time and overrode the truncated beds of the Simpson group. In short, the erratic masses are klippen.

## INTRODUCTION

Concentrated exploration for conditions similar to the Fitts oil pool, located in the Franks graben in Pontotoc County, Oklahoma, was under way during the winter of 1934 and 1935. The writer was assigned the work of mapping the Mill Creek syncline, and areas adjacent to it in T. 1 and 2 S., R. 3, 4, and 5 E., Murray and Johnston counties, Oklahoma, to determine the possibilities of oil production of the region.

Interesting structural conditions were noted in a confined area south of the town of Sulphur. This is the outcrop area of pre-Pontotoc strata of the western extensions of the Belton anticline, Mill Creek syncline, and Sulphur syncline. As nearly as possible this report will deal with this restricted area.

The detail work was done under the direction of E. J. Boos. Many of the problems of the area were discussed with him. A. M. Meyer assisted the writer in numerous field trips to the area. All aspects of the area were freely discussed with him and much credit is due him for his excellent contributions and criticisms.

## TOPOGRAPHY

The Arbuckle Mountains are not mountains in a topographic sense, being such only in a geologic sense. At the present time their topographic expression is hardly more than low, rolling hills. They are only slightly elevated above the rolling plains on the north. The mountain area is, in fact, a highly dissected plateau. Elevations in the area vary from approximately 1,220 feet in the northeastern part to approximately 960 feet in the southwestern part. The topographic detail is the result of variations in hardness of the rock formations, giving rise to the present contour of the mountains. At one time the Arbuckle Mountains undoubtedly attained considerable height.

[1] Manuscript received, October 18, 1944.

[2] Phillips Petroleum Company.

## STRATIGRAPHY

### GENERAL

The outcropping strata embrace rocks from upper Arbuckle limestone to rocks equivalent in age to the Wapanucka limestone, as well as Lower and Middle Pennsylvanian rocks which have been downfaulted and folded into the Mill Creek syncline along its northern boundary. The Pontotoc conglomerates of Upper Pennsylvanian age overlap the Lower and Middle Pennsylvanian, as well as the Mississippian, Devonian, Silurian, and Ordovician formations.

The writer used and recognized a number of diagnostic macrofaunal forms for the identification of the various mappable units. No attempt was made to classify the various forms noted, since paleontologic classification has been well treated by others who have worked in the Arbuckle Mountains. In the main, the lithologic characteristics, together with other surface expressions, formed the basis for mapping the various units.

The thickness of the various geologic units was necessarily computed from dip and strike readings across the outcrop, since, at no locality were complete, well exposed, undisturbed sections available for detailed measurement.

### ORDOVICIAN

#### ARBUCKLE GROUP

The Arbuckle limestone crops out along the eastern border of the work on the Belton anticline. Only the upper beds of this formation were examined, Those examined comprise a section not more than a few hundred feet in thickness. The upper Arbuckle strata are composed chiefly of finely crystalline to granular, light gray to greenish, thinly bedded, dolomitic limestones, with some thin, sandy and shaly beds.

#### SIMPSON GROUP

The Simpson group southeast of Sulphur is exposed on the western extension of the Belton anticline. These strata dip northwestward at a low angle and the progressively younger beds occur toward the west. In the downfolded rocks of the Sulphur syncline, the upper members of the Simpson group are present, dipping northward and northeastward at relatively high angles. In the highly folded area of the Mill Creek syncline, the Simpson group is exposed along the northern limits of the syncline. The beds dip steeply southward and southwestward away from the Belton anticline.

The Simpson group has a thickness of 1,922 feet in Secs. 31 and 32, T. 1 S., R. 4 E. With a like allowance for the Joins formation as measured in Sec. 32, T. 1 S., R. 4 E., the Simpson group has a total thickness of 1,779 feet in Secs. 12 and 13, T. 1 S., R. 3 E. The beds correlated as Simpson rocks in the dry hole in the NE.$\frac{1}{4}$, NE.$\frac{1}{4}$, SW.$\frac{1}{4}$ of Sec. 36, T. 1 S., R. 3 E., have a total thickness of 1,800 feet. With an allowance of 100 feet for beds in the Bromide, which, in this well, appear to be removed by faulting, the total thickness would be approximately 1,900 feet.

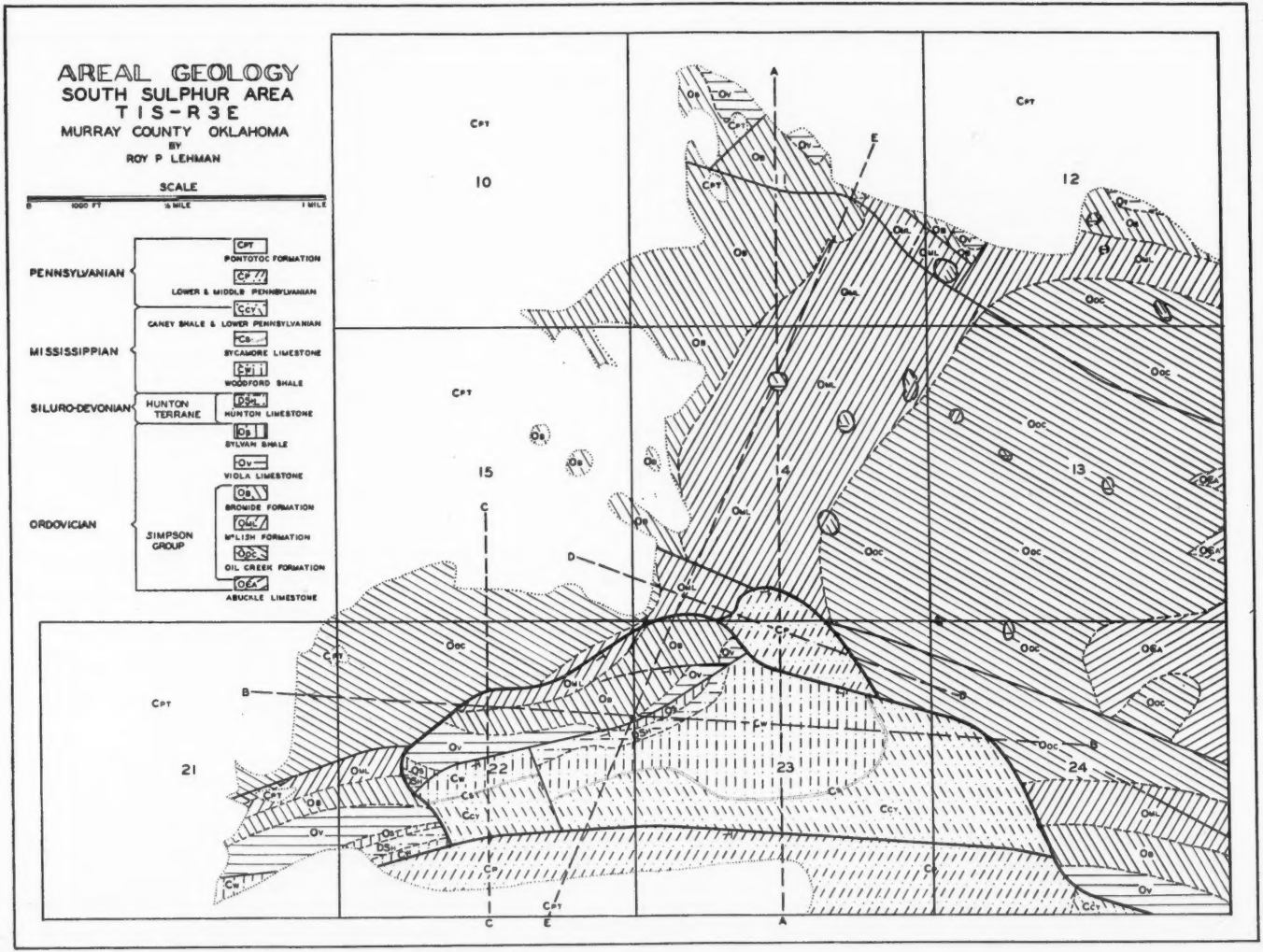
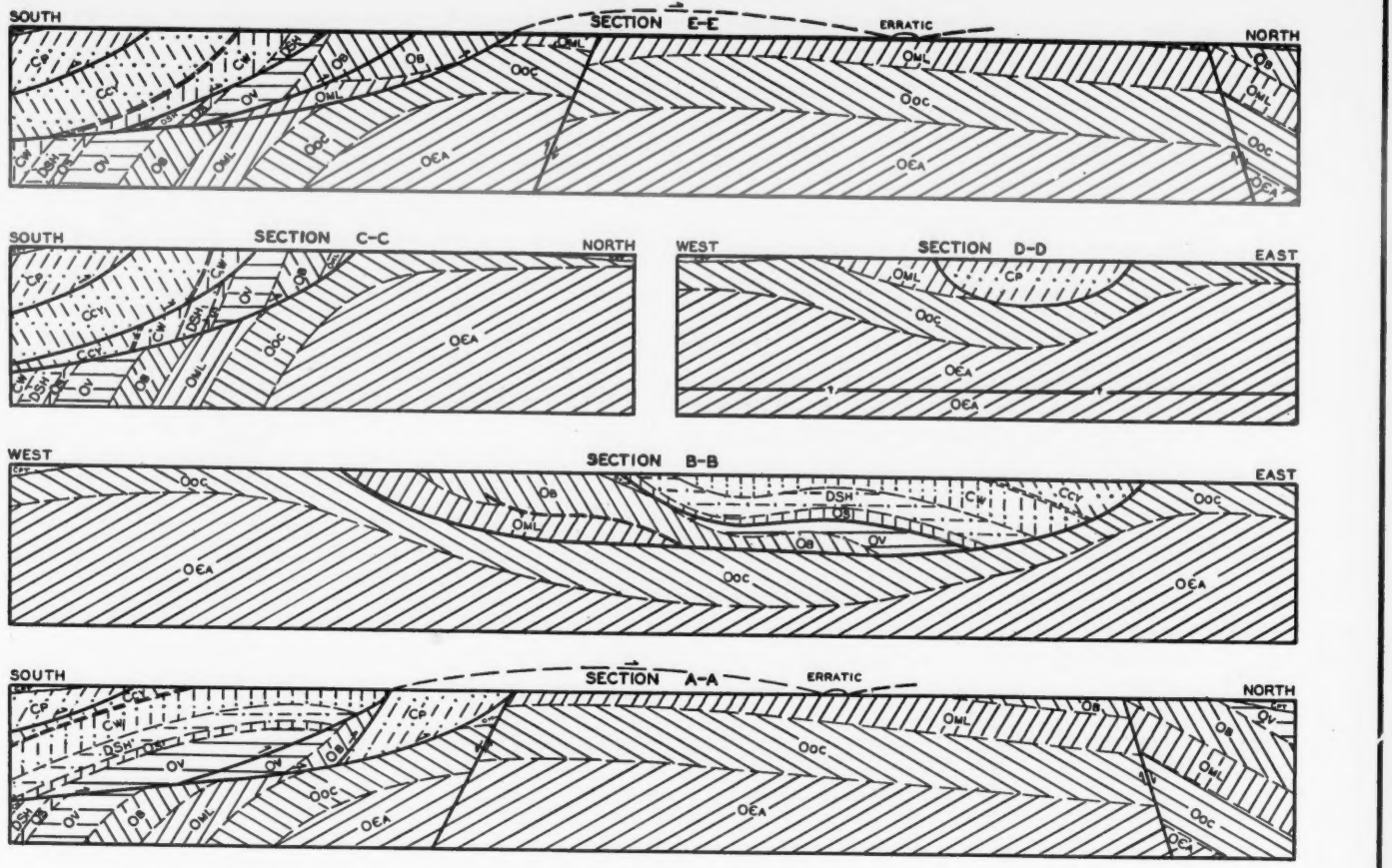

AREAL GEOLOGY
SOUTH SULPHUR AREA
T 1 S - R 3 E
MURRAY COUNTY OKLAHOMA
BY
ROY P LEHMAN
SCALE
0 1000 FT ½ MILE 1 MILE
PENNSYLVANIAN
MISSISSIPPIAN
SILURO-DEVONIAN
ORDOVICIAN
HUNTON TERRANE
SIMPSON GROUP
PONTOTOC FORMATION
LOWER & MIDDLE PENNSYLVANIAN
CANEY SHALE & LOWER PENNSYLVANIAN
SYCAMORE LIMESTONE
WOODFORD SHALE
HUNTON LIMESTONE
SYLVAN SHALE
VIOLA LIMESTONE
BROMIDE FORMATION
McLISH FORMATION
OIL CREEK FORMATION
ABUCKLE LIMESTONE
10
12
15
14
13
21
22
23
24
A
B
C
D
E

FIG. 1




IDEALIZED CROSS SECTIONS
SOUTH SULPHUR AREA

FIG. 2

*Joins formation.*—The Joins formation is exposed in the eastern part of the mapped area, but has not been mapped as a separate unit in this work. It was included with the Arbuckle limestone. These strata are composed of thinly bedded, light gray to greenish, finely crystalline, dolomitic limestones interbedded with thin beds of green shale, and some sandstone. The sandstone is more prevalent in the basal part. The limestones of the Joins formation are lithologically very similar to those of the upper Arbuckle limestones. It is for this reason they were not mapped as a separate unit. The beds assigned to the Joins formation have a measured thickness of 209 feet in Sec. 32, T. 1 S., R. 4 E.

*Oil Creek formation.*—The Oil Creek formation can be divided into two units. The lowermost member is composed of massive sandstones containing a few shale and limestone beds. The upper member is composed chiefly of gray, thinly bedded coarsely to finely crystalline limestones, with varying amounts of shale. The limestones on the weathered surface are rough, brown, and highly fossiliferous. The shales are invariably green to green-gray in color. This upper unit of the Oil Creek formation is the most easily recognized part of the Simpson formation.

The thickness of the Oil Creek formation in Sec. 13, T. 1 S., R. 3 E., has been computed to be 647 feet. The basal sandstone member is 330 feet thick and the upper limestone member has a thickness of 317 feet. Lithologically the Oil Creek rocks appear to be somewhat changed in Sec. 21, T. 1 S., R. 3 E. The upper limestone member is similar in thickness to the section exposed in Sec. 13, T. 1 S., R. 3 E., but the lower sandstone member has changed to the extent that the upper part of the member is largely green shale and thin limestone. The basal sandstone near the large asphalt quarry in Secs. 15 and 22, T. 1 S., R. 3 E., is not thought to be more than 150 feet in thickness. No accurate measurement, however, is possible. The thickness of the Oil Creek formation is computed at 611 feet in Sec. 32, T. 1 S., R. 4 E. The limestone member has an average thickness of 232 feet, and the lower sandstone member has a thickness of 379 feet. The Oil Creek formation is correlated as representing 670 feet of rocks in the well drilled in the NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 36, T. 1 S., R. 3 E. The upper 300 feet is limestone and shale, and the lower 370 feet represents the basal sandstone member.

*McLish formation.*—The McLish formation cartographically, like the Oil Creek formation, has two units. An upper limestone member crops out in a slightly raised, rounded ridge. The lower sandstone member is ordinarily expressed topographically by stream valleys. The lower sandstone member is composed of massive to cross-bedded sandstone, having a few shale beds. The upper limestone member is made up of light gray, thinly bedded, finely crystalline to lithographic limestone, and a few thin green shale, or shaly beds.

The upper limestone member in Sec. 14, T. 1 S., R. 3 E., has a thickness of 253 feet. The sandstone member is 168 feet thick. The total thickness of the formation in this locality is 421 feet. The upper member of the formation is 262 feet thick in Sec. 21, T. 1 S., R. 3 E. The limestone member is 268 feet thick in Sec. 22, T. 1 S., R. 3 E. The entire thickness of the formation is computed at 433 feet

FIG. 2

in Sec. 12, T. 1 S., R. 3 E. The McLish beds have a thickness of 476 feet farther southeast in Sec 31, T. 1 S., R. 4 E. The limestone member is 221 feet thick and the sandstone member 245 feet thick. The thickness of the formation is 441 feet and 459 feet as measured in two localities in Sec. 10, T. 2 S., R. 4 E. The thickness of the upper member is computed at 301 feet and 311 feet, respectively, and the lower member is respectively 140 feet and 148 feet in thickness. The beds correlated as representing the McLish formation in the dry hole drilled in the NE. ¼, NE. ¼, SW. ¼ of Sec. 36, T. 1 S., R. 3 E., are 430 feet thick. The limestone member is 230 feet thick and the sandstone member 200 feet thick.

*Bromide formation.*—The Bromide formation is composed of massive to thinly bedded limestone in the upper part and sandstone, shale, and limestone in varying amounts in the lower part. The limestone member at the top of the formation has the most conspicuous topographic development of any formation in the mountains. This member is resistant to weathering, and, with the overlying Viola limestone forms high, rounded topographic knobs easily recognized. The lower member of the formation is commonly the site of small drainages.

The thickness of the Bromide formation was difficult to determine because of several extraneous conditions, such as poor exposures, strike faulting, and the proximity of the Pontotoc overlap. A thickness of 490 feet was computed for the beds representing the Bromide formation in Sec. 12, T. 1 S., R. 3 E. On the west side of the area, in Sec. 21, T. 1 S., R. 3 E., a thickness of 310 feet of beds is assigned to the formation. The best exposed and least disturbed section crops out farther southeast in Sec. 31, T. 1 S., R. 4 E. The Bromide formation in this locality is computed to have a total thickness of 626 feet. There are 185 feet of limestones in the upper member, and 441 feet of limestones, shales, and sandstones compose the lower member. The lower member of the formation is 400 feet in thickness in the dry hole in the NE. ¼, NE. ¼, SW. ¼ of Sec. 36, T. 1 S., R. 3 E., and 90 feet of beds are correlated to represent the upper member of the formation. In this well it is evident, however, that some of the Viola limestone and possibly as much as 100 feet of the Bromide formation have been cut out by faulting.

### VIOLA GROUP

The Viola group occurs in both the Sulphur and Mill Creek synclines. It is found in four isolated, overlapped, and faulted localities in the Sulphur syncline. In the Mill Creek syncline it occurs in five faulted and discontinuous areas. The structure of the Viola group is similar to that of the underlying Simpson rocks. In addition to the foregoing occurrences, nine other localities were noted. These are in the form of slightly raised hills where rocks of the Viola limestone, associated with upper Simpson rocks, occur in a peculiar form.

The Viola limestone can be divided into two units. The lower unit (Trenton) is composed of light gray to buff, finely crystalline, thinly bedded limestones and interbedded cherts. The upper unit (Fernvale) is composed of gray to light gray,

massively bedded to thinly bedded, coarsely crystalline limestones. The lower cherty and finely crystalline member has an average thickness of 400 feet. The upper coarsely crystalline member has an average thickness of 80 feet. The thickness of the Viola group is 461 feet in Sec. 21, T. 1 S., R. 3 E. These rocks have a thickness of 420–550 feet in Secs. 30 and 31, T. 1 S., R. 4 E.

*Sylvan shale.*—The Sylvan shale crops out only in the Mill Creek syncline. It is found in three isolated localities in Secs. 22 and 23, T. 1 S., R. 3 E. The Sylvan shale is poorly exposed, since it forms a narrow valley between the more resistant Hunton and Viola limestones. This formation is the typical greenish gray, finely textured, slightly calcareous shale in the upper part, with a black, carbonaceous, slightly dolomitic shale in the basal part that has been described in other reports dealing with this formation in the mountains. The thickness of the formation was found to vary from 60 feet in Sec. 6, T. 2 S., R. 4 E., to 210 feet in Sec. 12, T. 2 S., R. 4 E. The average thickness of this formation is about 140 feet. Undoubtedly variations in thickness in different localities are largely due to flowage in the soft shale because of extreme folding.

### SILURO-DEVONIAN

### HUNTON GROUP

The Hunton group occurs only in the Mill Creek syncline. There are three isolated localities of outcrop which are the result of faulting. In each place the Hunton group overlies the Sylvan shale. The Hunton group forms a low, rounded ridge above the Sylvan shale and the lower Woodford shale. All four divisions, as described by Reeds, were recognized in the mapping. However, no attempt was made to map the several formations.

The Chimney Hill limestone, at the base of the Hunton group, has a thin, white to gray oölitic limestone as a basal member; a middle member of white, finely crystalline, glauconitic limestone; and an upper member of pink to white, finely to coarsely crystalline limestone. Small amounts of chert are present in the upper two members.

The Henryhouse shale and Haragan shale are lithologically very similar and could be divided only on the basis of the contained fossils. These formations consist of white to gray, soft, thinly bedded, marly limestones, with a few thin layers of resistant limestone.

The Bois D'Arc limestone at the top of the Hunton group is composed of white, coarsely crystalline limestone. This formation contains considerable interbedded chert in the upper part. This formation is not represented in all exposures of the Hunton group, being cut out by the pre-Woodford erosional interval. In one locality a thin, hard, quartzitic, asphaltic sandstone overlies the limestone.

Measured sections of the Hunton group in the Mill Creek syncline vary in thickness from 162 feet to 360 feet. The group has a thickness of 206–232 feet in Secs. 22 and 23, T. 1 S., R. 3 E.

MISSISSIPPIAN

*Woodford shale.*—The Woodford shale is exposed only in the Mill Creek syncline. It normally overlies the Hunton limestones unconformably. The westernmost exposure in Sec. 21, T. 1 S., R. 3 E., shows this formation in contact with the Viola limestone. This relationship is produced by faulting. The Woodford shale is exposed in its normal stratigraphic relationship a short distance eastward. This exposure is restricted by faulting and the overlapping of the Pontotoc conglomerates. Areas of exposure in two localities in Secs. 22 and 23, T. 1 S., R. 3 E., reveal this formation in contact with rocks of the Hunton and Viola as the result of faulting.

The Woodford shale is surficially expressed by a wooded ridge or slope. It is composed of gray to brown and black, thinly bedded, siliceous shales. The formation is the most readily recognized unit in the mountain area. Measured sections of the formation vary in thickness from 365 to 455 feet in the Mill Creek syncline. The formation has a thickness of 424 feet in Sec. 22, T. 1 S., R. 3 E.

*Sycamore limestone.*—The Sycamore limestone occurs above the Woodford shale in Secs. 22 and 23, T. 1 S., R. 3 E., and crops out only in the Mill Creek syncline.

The Sycamore limestone is bluish gray on fresh exposure, yellowish to brownish on weathered exposure, and is finely crystalline and slightly siliceous. The color of the weathered rock is very distinctive. It serves definitely to define the upper limits of the Woodford shale, which greatly resembles the overlying lower Caney shale. The Sycamore limestone has a thickness ranging from 1 to 5 feet in various exposures.

*Caney shale.*—Immediately overlying the Sycamore limestone is a series of gray to brownish shales succeeded by darker-colored shales. Numerous zones of limestone concretions were noted in the lower part. These shales are exposed only in the Mill Creek syncline in Secs. 22, 23 and 24, T. 1 S., R. 3 E. They weather rapidly and can be viewed only in isolated exposures. At no place is a measurement of their thickness possible.

PENNSYLVANIAN

*Lower Pennsylvanian.*—The Lower Pennsylvanian rocks are exposed only in the Mill Creek syncline where they have been downfaulted and highly folded between the older, more competent rocks of Mississippian, Devonian, Silurian, and Ordovician age. Lack of time for extensive study and poor exposures were the reasons for only a fair idea of their structure, lithologic character, and stratigraphic relationship.

At several localities beds of dark gray, soft fissile shale of Pennsylvanian Caney or Springer age were noted. These beds overlie the Mississippian Caney shales and are assumed to have a stratigraphic relationship similar to that of the Atoka basin, on the north, and the Ardmore basin, on the south.

The Springer shales are overlain by a sandstone and limestone series inter-

bedded with shale. This series has an approximate thickness of 450–500 feet. These beds of limestone and sandstone crop out from the town of Mill Creek westward for a distance of approximately 6 miles. In many outcrops, dips are very steep. The sandstones in this series are medium- to fine-grained and in many places are shaly. The limestones are bluish gray, finely crystalline, fossiliferous, and oölitic. In the restricted area of this report, a small exposure of these rocks occurs near the center of the south line of Sec. 24, T. 1 S., R. 3 E. These rocks are tentatively considered as being the correlative of the Wapanucka-Cromwell section of the Atoka basin.

*Lower and Middle Pennsylvania.*—Overlying the Lower Pennsylvanian rocks already described, is a series of sandstones, shales, and limestones interbedded with limestone conglomerates which comprise a considerable thickness of strata. There is a marked lithologic change from that in the Lower Pennsylvanian beds. These rocks northeast of Mill Creek can be seen in one place to overlap the oölitic limestone section of the underlying Lower Pennsylvanian. This overlapping condition is a marked change from the parallel bedding of the rocks below. An unconformity of considerable importance is indicated. Poor exposures made it impossible to determine the true stratigraphic relationships of this series within itself. However, the recurrent limestone conglomerates suggest possible sedimentary breaks of importance which may indicate further unconformity. These beds, like the Lower Pennsylvanian rocks, are steeply folded into the Mill Creek syncline. This series of rocks is correlated, at least in part, with the Des Moines and Missouri groups of central and northern Oklahoma, and the Deese and Hoxbar groups of the Ardmore basin.

*Upper Pennsylvanian.*—The Pontotoc comglomerates are exposed along the western border of the mountain area. They are composed of limestone conglomerates, sandstones, and shales, with a few beds of thin limestone. These beds can be seen to overlap all rocks ranging from the Middle Pennsylvanian to the Arbuckle limestone. Minor folding and faulting in the Pontotoc conglomerates were noted. These rocks have not been folded into the mountains as have all older strata. The attitude of the conglomerates does indicate, however, post-Pontotoc folding of some magnitude.

## Erratic Masses

### General

The occurrence of thirteen erratic masses on the truncated rocks of the Belton anticline and the Sulphur syncline is of special interest. These masses occur over an area of approximately 3 square miles in known outcrop. There are four in the area of the Sulphur syncline. The remaining nine occur on the Belton anticline. Some evidence was noted to indicate that other erratic masses may be present.

The thirteen erratic masses vary greatly in size.[3] The smallest is to be found

[3] W. E. Ham, personal communication dated January 19, 1945. A fourteenth erratic mass mapped and described in the SE. ¼, NW. ¼, NE. ¼ of Sec. 14, T. 1 S., R. 3 E., is reported by Mr. Ham. It is

in Sec. 12, T. 1 S., R. 3 E., and is approximately 90 feet in diameter. It is almost round in pattern. The largest mass is in Sec. 14, T. 1 S., R. 3 E. It measures 600 feet in length north and south, and 280 feet in breadth. There are three masses approaching a circular design. The remaining ten are oblong and are aligned northwest and southeast.

One mass is composed almost entirely of rocks of Viola (Trenton) age. The rocks in seven of the masses are of Viola (Trenton) and upper Bromide age. The remaining five are composed chiefly of Bromide and McLish rocks.

The internal structure of each erratic mass is extremely complex. The rocks themselves are highly broken and shattered, and many are "mixed." In most places, dips of the rocks of the erratic masses are very steep. In some places, the original boundary of the individual formations can be determined. The original bedding has been preserved. If there is any mappable structure in the individual masses, it appears to be synclinal. The general dip in the erratic masses seems to be toward the center of the mass. However, the rocks are so highly folded, faulted, and "mixed" that an individual structure can not be assigned to each of the masses, or any simple structure to any single mass. In general, it might be noted that the complexity of the structure is more pronounced in the smaller masses; this, however, is a matter of relative complexity, none being simple.

As previously stated, four erratic masses are superposed on the Sulphur syncline, all known masses being located in Sec. 12, T. 1 S., R. 3 E. The northernmost mass is approximately 2,350 feet west and 1,900 feet north of the southeast corner of the section. It is within about 100 feet of the overlapping Pontotoc conglomerates. Its position is slightly less than $\frac{1}{2}$ mile north of the fault and (or) flexure denoting the southern limit of the Sulphur syncline. This mass is elongate in a northwest-southeast axis. It is 290 feet in length and 200 feet in width. It is composed of Viola (Trenton) and upper Bromide rocks. The mass is superposed on rocks of Bromide age, dipping about 40° N.NE.

The smallest of the erratic masses is 2,150 feet west and 1,350 feet north of the southeast corner of Sec. 12, T. 1 S., R. 3 E. It is about 600 feet south-southeast of the previously described mass, and less than 500 feet from the Pontotoc overlap. This mass is almost circular and has a diameter of approximately 90 feet. It is composed of rocks of Viola (Trenton) age almost entirely. These rocks are highly shattered. The mass is situated on sandstone of the McLish formation. The underlying rocks dip northwest at about 35°.

One of the most evident and best exposed of the erratic masses is about 1,050 feet west and 250 feet north of the southeast corner of Sec. 12, T. 1 S., R. 3 E. It is approximately $\frac{1}{4}$ mile southwest of the Pontotoc overlap. It is the easternmost of the known erratics. Its position is about 1,500 feet north of the southern

circular in outline, having a diameter of 500 feet. The mass shows typical erratic dip. Many of the blocks are typical birdseye limestone, which are identified with the upper part of the McLish limestone. This mass is located about 300 feet north of the mass shown in Figure 3, and straddles the McLish sandstone-limestone contact. State Highway No. 18 cuts through the eastern edge of the mass.

limit of the Sulphur syncline. This mass is elongate northwest and southeast. It is 425 feet in length and 160 feet in width. The rocks of this mass are Viola (Trenton) and upper Bromide in age. The mass is situated on limestones of the Oil Creek formation, and slightly overlaps the upper sandstone member of the Oil Creek formation. The underlying Oil Creek limestones dip northward at about 30°.

The fourth mass which is superposed on the Sulphur syncline is 100 feet east and 1,000 feet north of the southwest corner of Sec. 12, T. 1 S., R. 3 E. It is within 750 feet of the Pontotoc overlap. This mass is only a few feet from the south boundary of the Sulphur syncline, and may slightly overlap the rocks of the Belton anticline. This mass is slightly elongate northwest and southeast. It is 480 feet in length and 400 feet in width. The rocks of this mass are thought to be lower Bromide and McLish in age. They are superposed on the limestones of the McLish formation, which dip about 40°NE.

There are nine known erratic masses on the Belton anticline. The easternmost is about 500 feet east and 300 feet south of the center of Sec. 13, T. 1 S., R. 3 E. It is approximately 1,700 feet southwest of the north limit of the Belton anticline. This mass is about $\frac{3}{4}$ mile south and $1\frac{1}{4}$ miles east of the Pontotoc overlap. It is slightly elongate, being 260 feet in length in a north-south axis, and 180 feet in width. It is composed of Viola (Trenton) and upper Bromide rocks. This mass is situated on the upper part of the sandstone member of the Oil Creek formation, with remnants of Oil Creek limestone underneath the mass. The Oil Creek rocks dip 8° NW.

A second mass, on the sandstone member of the Oil Creek formation, is 1,350 feet east and 200 feet south of the northwest corner of Sec. 24, T. 1 S., R. 3 E. It is slightly more than 1 mile east and $1\frac{1}{4}$ miles south of the Pontotoc overlap. It is the most remote from that overlap, and is about 900 feet north of the south limit of the Belton anticline. This mass is slightly elongate and irregular, with the long axis almost north-south. It has a length of about 330 feet and a width of 170 feet. The mass is composed of limestones of Viola (Trenton) and upper Bromide in age. As stated, this mass is on the upper standstones of the basal member of the Oil Creek formation, which are inclined westward at less than 10°.

At a point about 150 feet east of the southwest corner of Sec. 13, T. 1 S., R. 3 E., a small erratic mass of Viola (Trenton) and upper Bromide limestones is superposed on the lower limestones of the upper member of the Oil Creek formation. This mass is slightly elongate northwest and measures about 150 feet in length and 130 feet in width. The Oil Creek limestones dip approximately 7° W. This mass is about 700 feet north of the south limit of the Belton anticline. The rocks in the mass are highly broken, shattered, and "mixed," more so than in most of the masses. The rocks appear as a slightly raised hill and can be seen to lie on the Oil Creek limestones.

A fourth erratic mass on the Belton anticline occurs 1,300 feet east and 2,300 feet south of the northwest corner of Sec. 13, T. 1 S., R. 3 E. It is about 2,000

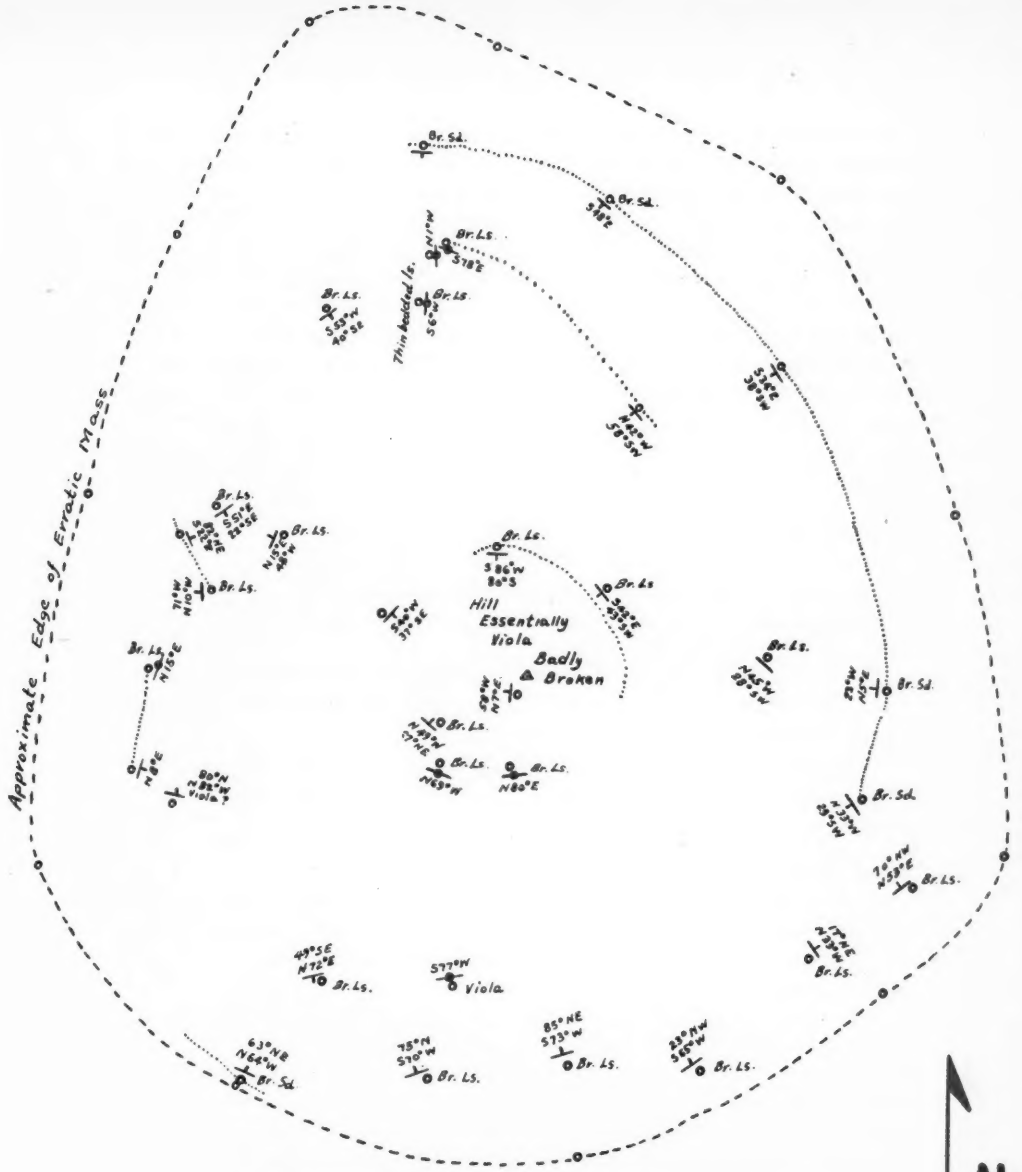
feet south of the north boundary of the Belton anticline. This mass is definitely elongate with a northwest-southeast axis. It is 120 feet in width and 250 feet in length. The rocks of this mass are Viola (Trenton), lower Bromide, and possibly McLish in age. The mass is situated on the limestones of the upper member of the Oil Creek formation. The underlying Oil Creek limestones dip about 7° or 8° NW.

A unique mass occurs about 1,000 feet northwest of the one last described. It is 450 feet east and 1,650 feet south of the northwest corner of Sec. 13, T. 1 S., R. 3 E. This mass has a position, with respect to the Belton anticline, similar to that of the mass just previously described, being slightly north of the anticlinal axis. It is circular in plan with a diameter of approximately 240 feet. This mass is almost entirely dense, gray limestone correlated with similar limestones in the McLish formation, but could possibly have been derived from beds in the basal part of the Bromide formation. There are some remnants of Viola (Trenton) limestone. This is the only erratic mass made up of these rocks. The mass lies on the limestones of the Oil Creek formation which dips about 8° NW.

At a distance of about 1,800 feet north of the south limit of the Belton anticline is an erratic mass of lower Bromide and McLish rocks partly superposed on the limestones at the top of the Oil Creek formation, and partly on the lowermost sandstones of the McLish formation. It is 1,800 feet west and 1,700 feet north of the southeast corner of Sec. 14, T. 1 S., R. 3 E. This mass is approximately 2,500 feet east of the Pontotoc overlap. It is elongate northwest and southeast, and covers an area approximately 420 feet in length and 330 feet in width. The limestones of the Oil Creek formation dip about 8° NW.

Located 350 feet west and 1,150 feet south of the northeast corner of Sec. 14, T. 1 S., R. 3 E., is the largest and one of the most prominent of the erratic masses. This mass is slightly more than $\frac{1}{2}$ mile south of the Pontotoc overlap and nearly $\frac{3}{4}$ mile east of that overlap. Its length is approximately 600 feet and its width 280 feet. It is elongate north and south. The rocks of this mass are thought to be lower Bromide or McLish in age and rest on the basal part of the sandstone member of the McLish formation. The dip of the rocks of the Belton anticline is about 8° NW. in this locality.

The most noticeable erratic mass from a topographic standpoint, and only slightly smaller than the largest mass, about $\frac{1}{4}$ mile northeast, is located about 1,500 feet west and 1,800 feet south of the northeast corner of Sec. 14, T. 1 S., R. 3 E. It is slightly more than $\frac{1}{2}$ mile east and 4,000 feet south of the Pontotoc overlap. It is in the center of the Belton anticline in a transverse direction. The mass is elongate northwest and southeast. It is approximately 375 feet in length and 310 feet in width. This mass, composed of Viola (Trenton) and upper Bromide rocks, forms a small, oblong hill on sandstones of the McLish formation. The structure of this mass, although highly complicated, has evidence of a general dip toward its center. The rocks of the underlying McLish formation are thought to be dipping, as in most places, 8° NW.




**ERRATIC MASS ON McLISH SAND**
**1800 S - 1500 W of NE COR 14-1S-3E**
**MURRAY CO. OKLA.**

0 50' 100'
SCALE

FIG. 3

The westernmost of the erratic masses is approximately 1,000 feet south of the center of the north line of Sec. 14, T. 1 S., R. 3 E. This mass is the nearest of the masses to the Pontotoc overlap of those superposed on the Belton anticline. It is slightly more than 1,000 feet east of that contact. Its location is near the center of the Belton anticline in a transverse direction. The general pattern of the mass is circular. It is about 325 feet in diameter. The rocks composing this mass are Viola (Trenton) and upper Bromide in age. The general structure of the mass is indicated to be synclinal by dips toward the center of the mass. It is at this mass that the clearest idea of the relationship of the rocks of the mass and the underlying rocks of the Belton anticline can be observed. A single limestone bed of the McLish limestone member, on which this mass rests, can be traced nearly to the north edge of the mass, and can also be noted without apparent disturbance near the south edge of the mass. The McLish limestones dip 8° NW.

### Comparison of Erratic Masses of Arbuckle Region with Erratic Boulders of Ouachita Region

The erratic masses south of Sulphur in the northern Arbuckle Mountains may raise the question of origin similar to that propounded by various authors for erratic boulders of the Ouachita area.

The erratic boulders of the Ouachita area approach in size, and some exceed in size, the erratic masses in the Sulphur area. The erratic boulders, in general, however, are much smaller.

The erratic boulders of the Ouachita region are more widespread, occurring throughout the area of the outcrop of the Johns Valley shale in the Ouachita Mountains. The area containing these exposures is approximately 20 miles in width and 125 miles in length. The erratic masses of the Sulphur area occur in an area of approximately 3 square miles.

The erratic boulders of the Ouachita region are described as being inclusions within the Johns Valley shale. As nearly as is known at present, there is no indication that the erratic masses at Sulphur have ever been included in any strata since their placement.

There is considerable difference in the age of the rocks in the erratic masses of the Sulphur area and the erratic boulders of the Ouachita area. The erratic boulders range in age from Lower Pennsylvanian limestone to Arbuckle limestone, while the age range of the erratic masses, as far as is known, is restricted to rocks ranging from Viola (Trenton) to McLish.

In all descriptions of the many erratic boulders of the Ouachita region, and in observations of the writer, no mention or note has been made of deformation within the erratic boulders themselves, with the exception of striae and rotational movement. The erratic masses of the Sulphur area, as indicated in the previous discussion, are highly shattered, broken, and "mixed."

A further difference in the erratic boulders of the Ouachita area from the

erratic masses as they occur in the Sulphur area is to be found in the exotic nature of the boulders in the Ouachita Johns Valley shale; that is, the boulders included in the Johns Valley shale are of a facies different from that of the known underlying Ordovician and in some places the Siluro-Devonian rocks of the Ouachita Mountains themselves. The erratic masses in northern Arbuckle Mountains can not be classified as exotic, since the rocks making up the individual masses are the same as the rocks in the near-by outcrop.

All available data would indicate that the age of the erratic boulders of the Ouachita region is possibly Johns Valley since they are included in the Johns Valley shales. This age assignment to the erratic boulders would apply to all theories with respect to their origin, with the exception of thrust faulting. If their origin is from thrust faulting, the date of accumulation of the boulders in the Johns Valley shale would then be the date of folding in the mountains and not necessarily the age of the Johns Valley shale in which they are included. The erratic masses of the northern Arbuckles are thought to be post-Hoxbar-pre-Pontotoc in age, since they are superposed on the eroded and truncated Simpson rocks. No positive evidence is available to indicate that they are not post-Pontotoc. However, the attitude of the erratic masses and the observed field relations strongly suggest that they were present before the deposition of the Pontotoc conglomerates and suffered erosion along with the underlying Simpson rocks.

## Origin of Erratic Masses

### GENERAL

The origin of the erratic masses south of Sulphur presents many and varied perplexing problems. Many of the questions which arise in the attempt at a logical solution of their origin are closely related to the physiographic, structural, and orogenic history of the mountains themselves.

An attempt is made to state certain possibilities of origin, which, in the course of the writer's study, have presented themselves. The facts in each case, as well as the fallacies, are stated as each possibility is presented.

### OUTLIERS OF PONTOTOC OVERLAP

The possibility of explaining the origin of the erratic masses as outliers of the Pontotoc overlap has been entertained. These masses are 100 feet to $1\frac{1}{4}$ miles of the present outcrop of the Pontotoc overlap. Outliers are found in many places at distances exceeding those here observed. The distance from the present Pontotoc outcrop is certainly within reason. Pontotoc outliers are present in several localities in this area. They do not, however, occur at as great a distance from the present outcrop of the overlap as do some of the erratic masses. In eliminating this possibility of origin, a study of several of the masses is sufficient to convince one that the materials in the masses are much different from the

rounded, weathered conglomerates of the Pontotoc. The material of each mass is well restricted, in most places, to short intervals in the stratigraphic section, whereas the material of the Pontotoc is truly a conglomerate. There is also a marked degree of preservation of the original bedding of rocks in the erratic masses. Nowhere is the original bedding of the derived rock preserved within the Pontotoc conglomerates. Further, the degree of weathering of the materials and the secondary deposition are highly different in the masses and in the Pontotoc conglomerates.

### CIRCULAR FAULTS

Downfaulting of an extreme type, such as would allow these circular and elongate masses to be displaced, has been suggested as a possible origin. This possibility is easily eliminated by the examination in the field. There is no direct evidence that such faults are present. In all instances, except one, there is no faulting in the rocks of the Belton anticline and Sulphur syncline near to the erratic masses to allow this possibility any credance whatsoever. For a singular case, such a complicated fault might be possible. However, when viewed in the light of the necessity of twelve exactly similar cases in so small an area, it is preposterous.

### EROSIONAL SLUMPING

A third possibility of origin, that of erosional slumping to account for the erratic masses, has been considered. In order to credit this as a possibility, it would be necessary for the rocks now appearing in the erratic masses to have suffered erosional slumping in excess of 1,700 feet for those masses superposed on the Oil Creek sandstones. The probability of slumping of the materials comprising the erratic masses for so great a vertical and stratigraphic distance through the varied section of rocks of the Simpson formation without the aid of structural forces seems impossible. The occurrence of the erratic masses on both the Belton anticline and the Sulphur syncline presents difficulties in explaining the erosional slumping theory. As in the case of circular faulting, the explanation of a singular mass would not entail the difficulties that would arise in the explanation of twelve like masses.

### GLACIATION

Glaciation within the Arbuckle Mountains, if present during late Pennsylvanian time from Hoxbar to Pontotoc, might have produced erratic masses of the type in the Sulphur area. In the field examination, no direct evidence of glaciation was noted in the form of glacial striae in the rocks of the masses or otherwise. No evidence of glacial pebbles or cobbles, roches moutonnées, eskers, moraines, drift, or other type of glacial débris was noted.

### NORMAL FAULTING

The possible presence of a normal fault scarp in the area, of sufficient magnitude to allow the placement of the erratic masses in their present position, has

been carefully considered. Cursory study of the area is all that is necessary to determine that faulting of sufficient magnitude is present. The possibility of a scarp on the north, allowing the placement of the erratic masses, can immediately be dismissed because of the presence of erratic masses on the Sulphur syncline as well as the Belton anticline. Faulting north of the present exposure of Ordovician rocks in the Sulphur syncline is not entirely eliminated. However, no faulting is known within a reasonable distance which could have produced the masses. A fault scarp of several thousand feet in height on the south would have been necessary. If such an escarpment had been present, and had there been a collection of large masses within the talus north of the fault, and had subsequent erosion removed the less resistant and smaller materials of the talus, the erratic masses could have been deposited.

The most serious objection to derivation of the erratic masses from a normal fault scarp arises from the fault itself, not in the material now making up the masses, or the placement of the masses in their present positions. As noted, nine of the erratic masses are wholly on the Belton anticline. Since the Belton anticline is one of the major mountain structural features, the possibility of an upthrown mass at the south, in the Mill Creek syncline, seems unlikely. If, however, the Belton anticline and Sulphur syncline during middle and late Pennsylvanian were synclinal and an upthrown block in normal position were present in the position of the Mill Creek syncline, the fault escarpment might have been a source. The location of the fault scarp can hardly be reckoned south of the present limit of the Mill Creek syncline, since no erratic masses are known to be present in the area of the Mill Creek syncline itself. An assumption that the erratic masses might have originated from a fault scarp of normal relationship seems contrary to the structural history of the mountains and therefore must be highly questioned.

### THRUST FAULTING

The possibility that thrust faulting might have produced erratic masses of the type noted south of Sulphur deserves consideration. There are two possibilities of this nature. However, they are merely a difference in degree. The first possibility is that of a low-angle overthrust where the thrust sheet was superposed on the eroded surface of the Belton anticline and Sulphur syncline. The subsequent erosion of the major part of the thrust sheet might have left the present erratic masses in somewhat the form they are at the present time. The erratic masses would then assume the category of klippen.

The second possibility, that of a relatively high-angle overthrust, would preclude a thrustal or compressional movement in the Mill Creek syncline at a time subsequent to the initial erosion of the Belton anticline and the Sulphur syncline. The resulting fault scarp would then have been able to furnish blocks which were deposited on the eroded and truncated rocks of the Belton anticline and Sulphur syncline. Later erosion would have then been necessary to remove the talus and

detrital material which collected in front of the fault scarp, leaving the present erratic masses in approximately their present form prior to the overlap of the Pontotoc conglomerates.

The areal geology of the Mill Creek syncline reveals some peculiar and pertinent data which suggest thrustal movement in a position that strongly supports one or the other of the foregoing two contentions relative to the origin of the erratic masses. It is noted on the areal geologic map that a small area of steeply dipping rocks of Pennsylvanian age is present near the center of the north line of Sec. 23, T. 1 S., R. 3 E., between Upper Ordovician, Siluro-Devonian, and Mississippian rocks of the Mill Creek syncline and Ordovician (McLish) rocks of the Belton anticline. The presence of this block of Pennsylvanian rocks in such a position indicates rather conclusively that thrust faulting is necessary to have produced this situation. The small outlier of Pennsylvanian rocks wedged between the older sediments presents many and varied problems. Is it now in its original position having been overridden by the thrust mass? Or, was it a separate part of the thrustal movement and in its present position because of this movement? In speculation on the possibilities, more questions than answers are possible.

The areal geologic map shows that the trace of the fault south of the Pennsylvanian outlier is considerably curved. It bends back sharply toward the south-southeast near the center of the west half of Sec. 22, T. 1 S., R. 3 E., at nearly a right angle to its normal course. The sinuous trace of this fault is good evidence of thrustal movement. Further study of the segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks indicates that a smaller segment of Woodford rocks near the center of Sec. 22, T. 1 S., R. 3 E., has moved over rocks of Hunton, Sylvan, and Viola age of the larger segment. This smaller segment has likewise moved a distance of 500 feet northward with respect to the segment immediately east. The east segment of Woodford and Hunton rocks appear to have moved over the Viola and Bromide of the segment on the north. Furthermore, the entire segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks south of the small Pennsylvanian outlier appears to have moved northward with respect to the area on the west a distance of 1,300 feet for the Hunton limestone and 1,600 feet for the Viola limestone. In addition, there appears to have been a rotational movement which has moved the east end of the entire segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks northwestward from the Viola, Bromide, and McLish rocks in Sec. 24, T. 1 S., R. 3 E. This movement would have displaced the segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks a distance of about 7,000 feet at the Viola-Bromide contact. This calculated movement is measured in the more stable part of the segment of Mississippian, Siluro-Devonian, and Upper Ordovician rock.

The weight of evidence suggests to the writer that the origin of the erratic masses was in thrustal movement. Any conclusions about the type of thrustal movement must be derived from the areal distribution of the rocks, the structure

of the rocks, and the structural history of the area. Concrete information about the hade of the faults is lacking in the field data. The curved nature of the fault suggets a low-angle fault plane. Although there is overturning in the segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks, or the thrust segment, the overturning has not been to the extent normally deemed necessary for a low-angle thrust. The position of the erratic masses northeast of the thrusted segment of Mississippian, Siluro-Devonian, and Upper Ordovician rocks roughly in alignment with that segment, is worthy of note. The areal distribution of Upper Ordovician rocks in the thrust segment causes one to wonder if the origin of the erratic masses is not indicated by this areal distribution. There appears to have been rotational movement toward the northwest for a distance of approximately 7,000 feet. The thrustal movement, thought to have been from the southwest, may have deposited part of the thrust segment as a sheet on the eroded and upturned rocks of the Belton anticline and Sulphur snycline. Extensive erosion followed, leaving the erratic masses as restricted remnants.

The thrusted mass is thought to have been produced in post-Hoxbar time, as evidenced by the overriding of the small Pennsylvanian outlier. The placement and erosion of the erratic masses in nearly their present form was completed before the deposition of the overlapping Pontotoc conglomerates. The agencies of erosion must have been extremely severe to have denuded the upthrust part of the Mill Creek syncline at a rate equal to the erosion of the thrust sheet and the surrounding mountain area. This rapid erosion is also shown in the composition of the Pontotoc conglomerates. A fault scarp of enormous height would not have been necessary and the thrust sheet would not have needed to have disturbed the general contour of the mountains to any large degree.

If the thrust fault were of the high-angle type and the erratic masses the result of collection of large blocks in the talus at the foot of the fault scarp, the fault scarp would necessarily have been relatively high, if one considers the position of the most distant of the erratic masses at slightly under 2 miles from the fault. The denudation of the thrusted segment to a point at or below the level of the erratic masses is difficult to conceive. The assumption of severe and rapid erosion which probably was taking place would be hard to imagine since the broken talus material would certainly have been removed much more easily and rapidly than the material of the consolidated thrust segment.

In a study of the structural features of the upper regions of the Mill Creek syncline, other evidence of compressional forces is to be noted. In these cases, the data indicate that the major associated faulting is of the thrust type, but of relatively high angle. The east part of the Mill Creek syncline is highly restricted. The more stable blocks of the Tishomingo anticline on the south and Belton anticline on the north not only have created a very active compressional force, but also have had an effect in the less competent rocks comparable with underthrusting. This has resulted in high-angle thrust faulting.

As has been shown, the various facts or inferences relative to the type of fault-

ing that might have produced the erratic masses is contradictory. The inferences about the upper part of the Mill Creek syncline point to faulting of high-angle type. The data available near the erratic masses, however, are contradictory and suggest faulting of the low-angle type. In reviewing and evaluating these data, the writer has concluded that the origin of the erratic masses is thrust faulting in the Mill Creek syncline and that such faulting probably was of a low-angle type. In short, the present erratic masses are klippen.

## Structural History of Arbuckle Mountains

In the discussion of the origin of the erratic masses in the area south of Sulphur, it was necessary to consider the structural history of the Arbuckle Mountains. This treatment of structural history was confined only to the forces necessary for the formation of the erratic masses.

All formations from the Arbuckle limestone to and including the strata of Lower Pennsylvanian age, as exposed in the Mill Creek syncline, are essentially parallel-bedded; that is, no large angular unconformity is present in those series of rocks. There are, however, minor breaks in deposition. In one place, at least, an erosional break of continental scope is present.

In the Arbuckle limestone several breaks in deposition are probably present, as suggested by brecciated limestones contained in it. The deposition of the Arbuckle limestone probably took place in a well defined basin or geosyncline which had only minor movements to disturb or interrupt deposition. The same condition is probably applicable to the Simpson rocks. Minor oscillation of the seas, much more pronounced than during Arbuckle time, produced a series of rocks much more varied in character than the Arbuckle limestone. The thick basal sandstones of the Oil Creek, McLish, and Bromide formations, at least in local development, suggest possible breaks in deposition. Field data point to a minor erosional interval between Viola (Trenton) and Bromide time. This, however, as near as could be ascertained, was local and did not disturb greatly the parallelism of bedding. Subsurface data north of the Arbuckle Mountains indicate that a break of some importance may be present between lower Viola (Trenton) and upper Viola (Fernvale) time. No evidence of a time break between the Fernvale and Sylvan was noted in the field data. During Siluro-Devonian time one break of some consequence is noted. This occurs between the Haragan and Henryhouse marls. This break, furnishing evidence of an erosional interval, does not, however, disturb the general conformity of the bedding.

An erosional interval of importance took place between the deposition of the Bois D'Arc limestone and the deposition of the overlying Woodford shales. This angular unconformity was not found to disturb the parallelism of bedding of the formations to any marked degree. In other areas it is known to have considerably more importance. This unconformity represents a movement of continental scope which did not contribute to the orogeny of the Arbuckle Mountains.

The overlying Mississippian and Pennsylvanian rocks studied in the Mill

Creek syncline appear to be parallel-bedded up to and including the series of rocks correlated with Morrow. It is believed that this same relation is generally true for the areas north and south of the mountains where the rocks have been studied in the subsurface.

Thus, from Arbuckle time to and including Morrow time no evidence is available to indicate that the sedimentary basin, which is now the Arbuckle Mountains, was greatly disturbed. In other words, the orogenic movement that produced the Arbuckle Mountains occurred after the deposition of these beds.

An angular unconformity is present in the Arbuckle Mountains which is post-Morrow in age. This is evidenced by the angularity of bedding between the rocks of Morrow time and those of Deese time. The rocks of Deese age can be seen to overlap those of Morrow age northwest of the town of Mill Creek. This angularity in bedding probably places the original movement in this part of the Arbuckle Mountains in early Atoka time. Some evidence is at hand to suggest that the initial folding started in the east part of the mountains and, as the folding progressed, it gradually affected parts of the mountains westwardly. The presence of limestone conglomerate beds in the series, which are correlated with the Des Moines and Missouri group, suggests that folding may have occurred at several periods during their deposition.

Evidence north of the Arbuckle Mountains indicates that at least three interim periods of folding took place. These are pre-Thruman, pre-Wewoka, and pre-Vamoosa. The final folding took place in pre-Pontotoc time since beds of Pontotoc age overlap strata of all preceding depositions. The folding was probably progressive in a westward direction from Atoka to Pontotoc time. Some folding took place post-Pontotoc, but this folding was minor and probably contributed little to the structure of the mountains. During late Pennsylvanian and Permian time the mountains were being worn down to a rather flat plane and were subsequently overlapped by Cretaceous sediments after being downfolded.

Thus, the two major periods of folding occurred in early Atoka and in pre-Pontotoc time. The former saw the beginning of the Arbuckle orogeny and the latter saw the end of the orogeny. Certainly the movement in the Wichita Mountains in post-Pontotoc time did affect the Arbuckle Mountains, but not in a mountain-building sense.

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VOL. 29, NO. 2 (FEBRUARY, 1945), PP. 210-214, 3 FIGS.

# GEOPHYSICAL HISTORY OF SOUTH HOUSTON SALT DOME AND OIL FIELD, HARRIS COUNTY, TEXAS[1]

J. BRIAN EBY[2]
Houston, Texas

## ABSTRACT

The South Houston salt dome was discovered by the Stanolind Oil and Gas Company, by use of the torsion balance, in May and June, 1934.

The structure was confirmed a few weeks later by reflection seismograph, by the Independent Exploration Company, under contract to the Stanolind.

The original gravity anomaly was partly obscured by the influence of a large regional gravity-minimum area, commonly referred to as the "Pearland regional minimum."

The discovery of the South Houston salt dome is unique in respect to the accuracy with which the domal uplift was localized and the very limited amount of work necessary to find it.

Subsequent drilling confirmed the salt dome, and oil was discovered in commercial quantities immediately thereafter.

The South Houston salt dome and oil field are several miles south and east of Houston, Harris County, Texas. The center of the dome is in the H. T. and B. Survey No. 5, the west flank extends into the Mary Nichols Survey and the north flank into the Callahan and Vince Survey. The town of South Houston is situated east of the dome.

The shape and size of the salt dome and the present extent of production are indicated in Figure 1. As shown on the map, the highest known salt occurs at a depth of 4,406 feet in the Stanolind Oil and Gas Company's well No. 1 in Block 19, or the center of the dome.

The salt plug is oval in outline, elongate N. 20° E. with the long axis on the 6,000-foot salt contour about 4,500 feet long, and the short axis is a little more than 3,000 feet long. The dome is one of the steepest in the Gulf Coast, and, due largely to its proximity to the town of South Houston, it was missed by all the early refraction-seismograph exploration parties operating in this county.

The present outline of production is indicated in Figure 1. It includes an area of about 650 acres, most of which lies northwest of the dome. Complicated faulting controls production and the south and east flanks of the dome, as drilled to date, have failed to produce.

There are two principal producing zones: Miocene sands, 3,800–4,100 feet; and *Marginulina* Frio sands at 4,500–4,900 feet in depth. The Miocene sands average 50 feet of saturation and the Oligocene sands about 150 feet of oil section. Most of the 91 oil wells in the field are flowing, producing 19°–25° gravity oil. The field has produced 10,870,000 barrels as of January 1, 1945.

The South Houston field was discovered by the Stanolind Oil and Gas Company by torsion balance in May and June, 1934. The party was directed by N. P. Teague and used three Z-bar type Bamberg balances. Robert H. Ray,[3] geo-

[1] Manuscript received, December 8, 1944.

[2] Consulting geologist, 1404 Esperson Building.

[3] Rogers-Ray, Inc., geophysicists, Houston, Texas

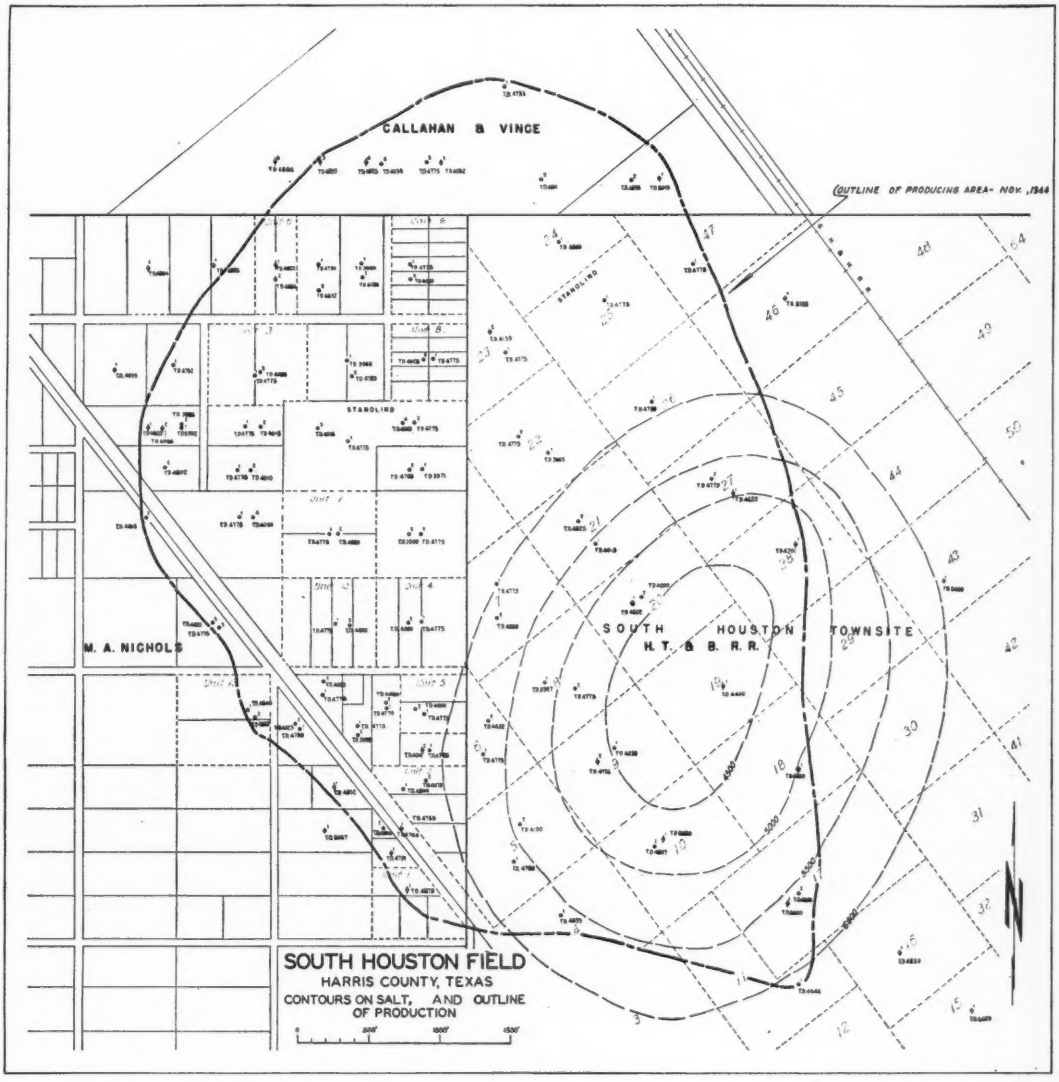
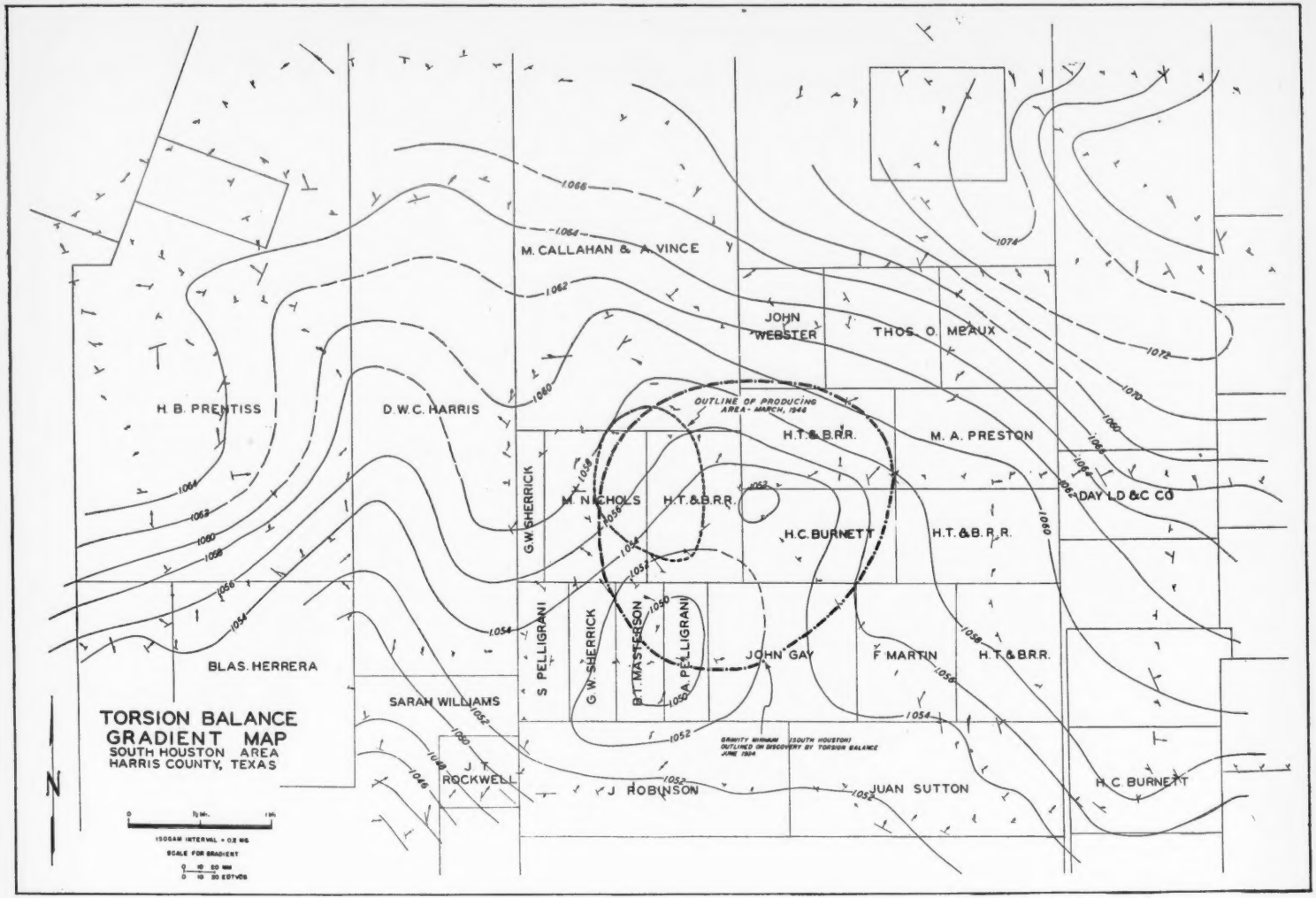

CALLAHAN & VINCE
(OUTLINE OF PRODUCING AREA- NOV. 1, 1944
STANOLIND
M. A. NICHOLS
SOUTH HOUSTON TOWNSITE
H. T. & B. R. R.
SOUTH HOUSTON FIELD
HARRIS COUNTY, TEXAS
CONTOURS ON SALT, AND OUTLINE OF PRODUCTION
5000
5300
5600
5900
6200
6500
N

FIG. 1


TORSION BALANCE
GRADIENT MAP
SOUTH HOUSTON AREA
HARRIS COUNTY, TEXAS
N
M. CALLAHAN & A. VINCE
JOHN WEBSTER
THOS. O. MEAUX
H. B. PRENTISS
D.W.C. HARRIS
OUTLINE OF PRODUCING AREA - MARCH, 1948
H.T.&B.R.R.
M. A. PRESTON
DAY L.D.&C. CO
G.W. SHERRICK
M. NICHOLS
H.T.&B.R.R.
H.C. BURNETT
H.T.&B.R.R.
S. PELLIGRANI
G.W. SHERRICK
BT. MASTERSON
A. PELLIGRANI
JOHN GAY
F. MARTIN
H.T.&B.R.R.
BLAS. HERRERA
SARAH WILLIAMS
J. T. ROCKWELL
J. ROBINSON
JUAN SUTTON
H.C. BURNETT
GRAVITY MINIMUM (SOUTH HOUSTON) OUTLINED ON DISCOVERY BY TORSION BALANCE JUNE 1924
1066
1064
1062
1060
1058
1056
1054
1052
1050
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1046
1074
1072
1070
1068
1066
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1046
ISOGAM INTERVAL = 0.2 MG.
SCALE FOR GRADIENT

FIG. 2

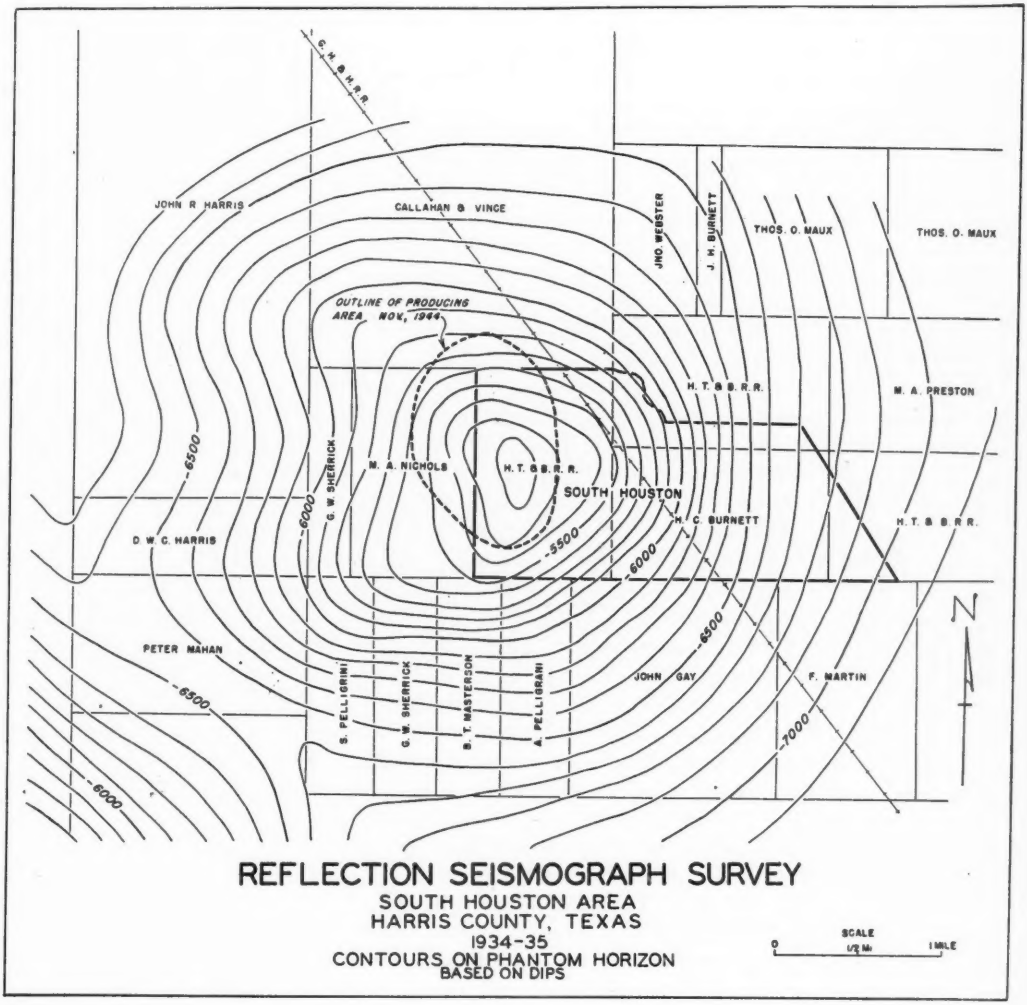
G. H. & H. R. R.
JOHN R. HARRIS
CALLAHAN & VINCE
JNO. WEBSTER
J. H. BURNETT
THOS. O. MAUX
THOS. O. MAUX
OUTLINE OF PRODUCING AREA NOV. 1944
H. T. & B. R. R.
M. A. PRESTON
M. A. NICHOLS
H. T. & B. R. R.
SOUTH HOUSTON
G. W. SHERRICK
H. C. BURNETT
H. T. & B. R. R.
D. W. C. HARRIS
6500
6000
5500
6000
6500
7000
PETER MAHAN
S. PELLIGRINI
G. W. SHERRICK
B. T. MASTERSON
A. PELLIGRAM
JOHN GAY
F. MARTIN
N
REFLECTION SEISMOGRAPH SURVEY
SOUTH HOUSTON AREA
HARRIS COUNTY, TEXAS
1934-35
CONTOURS ON PHANTOM HORIZON
BASED ON DIPS
SCALE
0
1/2 Mi.
1 MILE

FIG. 3

FIG. 2

physicist for the Stanolind at that time, was in charge of the investigation and recognized the South Houston minimum as a possible salt-dome anomaly. The gravity picture at South Houston and vicinity is indicated by Figure 2.

The South Houston anomaly falls on the northeast flank of what is commonly known as the Pearland regional gravity-minimum system. The South Houston anomaly, according to Ray,[4] appeared on the true total gravity map as a northeast minimum nosing out of the regional gravity pattern. This indicated the local South Houston anomaly, and, by making allowance for the normal northeast regional gravity change, the South Houston salt dome was interpreted as coinciding with the outline as shown in Figure 2. The outline of present oil production as appearing in Figure 1 is also shown to indicate the accuracy of the original torsion-balance survey. The gravity outline of the dome was drawn in June, 1934.

In view of the gravity information, the Stanolind placed a reflection-seismograph crew of the Independent Exploration Company in the area late in July, 1934. The party was directed by John W. Flude. It carried out highway traverses over the present known dome and with 3 days of work was able to pronounce the finding of a sharp domal uplift centering in the west center of the H. T. and B. Survey as shown in Figure 3. This 3-day shooting program demonstrated more than 800 feet of west, 1,400 feet of northwest, and 1,200 feet of north dip reversal. The normal dip in the coastal area is southeast. Due to the proximity of the South Houston townsite, a difficult lease problem was presented and final detailed shooting of the dome was not done until March, 1935, when 8 additional days of shooting was carried out by the same party. The original picture was not essentially changed, but additional data were obtained on the position of the syncline between the South Houston dome and the Mykawa dome at the southwest. The final reflection picture is that given in Figure 3 and the outline of present production is given to attest the accuracy of the early geophysical data.

The interesting features of the South Houston discovery are: (1) the local anomaly is obscure except in the light of the larger regional picture and (2) the reflection seismograph made possible accurate mapping in a short time. The domal feature was correctly appraised on the original 3-day shooting program. Subsequent drilling, as shown by the development map (Fig. 1), substantiated the geophysical data to a remarkable degree.

The writer is indebted to the Stanolind Oil and Gas Company for releasing the geophysical data on this structure. The coöperation of Robert H. Ray, who reviewed his early work in this area, is gratefully acknowledged. In the opinion of the writer it is important to preserve in the geological published record the geophysical maps and data on which notable dome and oil-field discoveries were made.

[4] Personal communication.

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# SIZE DISTRIBUTION OF SAND IN SOME DUNES, BEACHES, AND SANDSTONES[1]

W. D. KELLER[2]
Columbia, Missouri

## ABSTRACT

Sieve-analysis data from more than 700 sand samples collected from recent dunes and beaches, and from the St. Peter, Navajo, Wyopo, and Tensleep sandstones are used, following a simple procedure, to classify the sand samples as F or C. The ratio of the number of F samples to the number of C samples from a locality or formation gives its F:C ratio.

The F:C ratio for recent dune sand is relatively high; that for modern beach sand intermediate; and for the sandstone formations lowest of all three. The F:C ratio data indicate that the last environment of deposition of the four sandstones studied was not eolian.

## INTRODUCTION

A study of the size distribution of sand in recent dunes, beaches, and older sandstones was begun in 1939 in the hope of finding some correlation between the size distribution, or other characteristics, and the environment of deposition of the sand deposits. More than 800 sand samples were collected and sieved. From these data an empirical expression emerged which appears to permit some differentiation of environments of sand deposition. Publication of the results obtained to date seems to be merited rather than to delay until further sampling can be done, which must be postponed now (1944) because of the war.

Briefly, the sand samples are sieved and then classified as F or C samples, according to whether or not the larger of the two proximate grades is finer or coarser than the maximum grade. The ratio of F to C samples is determined and serves as a basis for differentiating beach and dune environments of deposition from each other. A more detailed explanation illustrated with data from this study follows.

## METHODS AND RESULTS

To compare sand of known beach environment with dune sand, both having the same source, collections were made along the Pacific Coast from the Columbia River south to San Diego. Twenty-seven localities were sampled along the coast, many of them furnishing a continuous suite from the beach inland to drifting dunes composed of sand transported from the ocean shore.

Additional dune collections were made from other western areas, namely, Death Valley, California; Pasco, Washington; Moses Lake, Washington; near Yuma, Arizona; in California; along the Columbia River; Dune Park, Indiana; and near Winnemucca, Nevada. These collections cover the main dune areas of western United States and should therefore represent dune sand from that part of the continent.

Furthermore, four thick, widespread, relatively "clean," quartz sandstones were sampled for comparison with the sands from the known dune and beach

[1] Manuscript received, December, 1944.

[2] Professor of geology, University of Missouri.

environments. The sandstones, furnishing 272 samples in all, are the St. Peter sandstone in Missouri, the Tensleep and Wyopo sandstones in Wyoming, and the Navajo sandstone in Utah.

Attention is directed to the fairly thorough and typical representation of western United States sands brought under study. It was believed that conclusions could be reached with assurance only if adequate experimental data were at hand; hence, the coverage given this area. Southern and eastern coasts should also be sampled but that must wait until post-war time.

At the laboratory, 100-gram samples of the loose sand or of disaggregated sandstones were sieved on a stack of Tyler sieves graduated in the following sizes.

| *Diameter Sieve Opening in Millimeters* | *Weight Percentage of Sand Remaining on Sieve* | |
|---|---|---|
| | *A* (Oo-4) | *B* (Oo-3) |
| 0.991 | | |
| 0.495 | 6 | 1 |
| 0.351 | 24 | 9 |
| 0.246 | 43 | 52 |
| 0.185 | 15 | 22 |
| 0.124 | 7 | 12 |
| 0.061 | 4 | 4 |
| Pan | 1 | 0 |

Two analyses, designated as A and B, are given as examples of "coarse" (C) and "fine" (F) samples, respectively. These designations, coarse and fine, are derived from the character of the larger of their proximate admixtures, a term proposed by Udden,[3] who wrote:

> In most samples . . . there is one medium grade, which is present in greater quantity than any other . . . will here be called the *chief ingredient* or the *maximum*. The ingredients in the grades nearest in size to its elements to the size of the elements in the maximum grade will be called the *proximate admixtures*.

Thus, in A in the foregoing table, the 43 per cent represents the chief ingredient, and 24 and 15 per cent the proximate admixtures.

In this study, the larger percentage of the two proximate admixtures describes the sample. Hence, in A, because the 24 per cent proximate-admixture fraction exceeds in quantity the 15 per cent proximate admixture, and because the 24 per cent proximate admixture is coarser than the maximum ingredient, sample A is classified a "coarse," or C, sample.

In like manner, in B, 52 per cent represents the chief ingredient, and 22 and 9 per cent the proximate admixtures. Here, since the proximate admixture finer than the maximum ingredient exceeds in quantity the coarser proximate admixture, B is designated as a "fine," or F, sample.

After the mechanical analyses of all the sand samples were completed and

[3] J. A. Udden, "Mechanical Composition of Clastic Sediments," *Bull. Geol. Soc. America*, Vol. 25 (1914), pp. 655–744.

classified as F or C, the ratio of the number of F samples to the number of C samples was computed for each group or formation. In the case of the Death Valley dune suite, 55 of the 60 samples collected were F samples, the other 5 being C samples. The F:C ratio for the Death Valley dune sand is therefore 55:5 or 11:1. This F:C ratio was the highest one for dune sands, but all the F:C ratios for dune sands were well above those for other environments. In contrast, the F:C ratio of 53 St. Peter sandstone samples is 0.9:1. This becomes interesting in connection with the origin of the St. Peter, a point to be discussed later. The suites of all localities were run, as described, with the following F:C ratio results.

| *Locality* | $\frac{F\ Samples}{C\ Samples}$ | *F:C Ratio* |
|---|---|---|
| Beach sand from 27 localities along the Pacific Coast from Columbia River to San Diego | $\frac{33}{30}$ | $\frac{1.1}{1}$ |
| Dune sand from the foregoing localities. Mainly from adjacent shore dunes | $\frac{55}{20}$ | $\frac{2.65}{1}$ |

It is obvious that the F:C ratio of dune sand from the Pacific Coast is considerably higher than that of beach sand from which the dune sand was blown.

Additional data on inland dunes whose sand was derived from sedimentary rocks, rivers, glacial deposits, and lakes support further a high F:C ratio for dune sand. The results of 370 samples follow.

| *Dune Locality* | $\frac{F\ Samples}{C\ Samples}$ | *F:C Ratio* |
|---|---|---|
| Death Valley, California | $\frac{55}{5}$ | 11:1 |
| Pasco, Washington | $\frac{12}{2}$ | 6:1 |
| Moses Lake, Washington | $\frac{72}{27}$ | 2.8:1 |
| Near Yuma, in California | $\frac{62}{25}$ | 2.5:1 |
| Columbia River, Oregon | $\frac{26}{5}$ | 5.2:1 |
| Dune Park, Indiana | $\frac{19}{6}$ | 3.2:1 |
| Winnemucca, Nevada | $\frac{47}{5}$ | 9.4:1 |
| Ratio for all of foregoing samples | $\frac{295}{75}$ | 3.9:1 |
| Ratio for all dune samples, including beach dunes | $\frac{351}{95}$ | 3.7:1 |

The lowest F:C ratios are found in the Moses Lake sand which is probably the coarsest of the group (average Md $\phi$ 2.26) and in the Yuma sand, one of the finest (average Md $\phi$ 2.81), but both of these sands have F:C ratios well above that of the Pacific beach sand. Certainly an F:C ratio of 2.5:1, or higher, is indicative of dune sand, according to the evidence from western United States dunes. One would expect an eolian sandstone likewise to have an F:C ratio within the range of the dune sands. In view of this expectation the data from 272 samples from the 4 sandstones in the following list become significant.

| *Formation* | $\frac{F\ Samples}{C\ Samples}$ | *F:C Ratio* |
|---|---|---|
| St. Peter sandstone | $\frac{25}{28}$ | 0.9:1 |
| Tensleep sandstone, Lander, Wyoming | $\frac{7}{17}$ | 0.4:1 |
| Wyopo sandstone, Lander, Wyoming | $\frac{4}{20}$ | 0.2:1 |
| Navajo sandstone, Zion National Park | $\frac{89}{82}$ | 1.1:1 |

Each of these formations has an F:C ratio well below that of any of the dune sands. In fact, none of these ratios is any higher than that of the Pacific beach sand, 1.1:1. These standstones may not have originated as beach deposits although their ratios approach that of Pacific beach sand, but they do not have F:C ratio characteristics of dune sand. Their sand may have existed in an intermediate stage as dune sand, but the evidence is against their having been last transported, sorted, or deposited in a dune environment.

In the case of the St. Peter sandstone this evidence supports Dake's[4] view: " . . . that the eolian theory of origin was untenable." In the cases of the other formations on which there is not complete agreement as to origin, the evidence presented herein is obviously opposed to a last-stage dune environment, and supports a non-eolian origin. Unfortunately, the interpretive value of the F:C data has greater negative strength than positive. If the sandstones are not eolian, presumably they are marine, most probably offshore deposits but possibly in part beach deposits. But whereas the F:C ratios do not strongly oppose a beach origin, such an interpretation can not be considered final, or even tentatively so, as long as knowledge of the F:C ratios of modern offshore sand deposits is lacking. Strong positive evidence would require close agreement with the ratios of one environment and negative evidence for the others.

The interpretation afforded by the F:C ratio concerning the origin of the

[4] C. L. Dake, "The Problem of the St. Peter Sandstone," *Bull. Missouri School of Mines and Metallurgy*, Vol. 6, No. 1, (1921).

four sandstones previously listed may thus be summarized: the evidence of the data from 272 of their samples and from 446 dune and beach sand samples is against an eolian origin.

### APPRAISAL OF F:C RATIO

The merits of the F:C ratio, as they appear, have been noted in the foregoing pages. Certain limitations, alternatives, and imperfections in the procedure have become evident since the work was begun and are discussed in the following paragraphs.

The F:C ratio is based on data obtained from an arbitrarily sized set of discrete sieve fractions of sand. The data are therefore subject to the limitations imposed by the choice of sieve sizes. With the sieves that were chosen in this investigation the sands fell into the F and C categories as reported, but George H. Otto[5] has pointed out that had a different sized set of sieves been used a different set of values might have been obtained. An extreme case of even reversal of F and C groups from the present ones could have resulted with an appropriate sieve set.

It is obvious, therefore, that the designations "coarse and fine" may not apply to the general case of continuous size distribution in sand, but under the conditions of the writer's empirical experiments the value of the letters F and C are not impaired. Even if the letters were reversed, and therefore the ratios were reversed, the values on dune sand would still differ as much from those of sandstones as shown in the F:C ratio. As a possible means of interpretation for sands the F:C ratio is good; as a statement of coarseness or fineness as would be shown by the cumulative curve it may not be of general application. Plans have been tentatively laid for exploration of the more general case by Otto and the writer, using the data of this investigation and some from other sources.

There is some indication that the F and C grouping may be a function in part of the median size of the sand. Further investigation probably will reveal a more fundamental difference between the results of different environments of deposition on the sizes of sand than that portrayed by the F:C ratio. In the meantime the present work is offered as a start. If the F and C grouping is related to the median size of the sand, some beach sands may be expected to show higher F:C ratios than those found by the writer on the Pacific Coast. However, if beach sand with a higher F:C ratio is to be found, it still does not affect the negative evidence of the non-dune origin for those sandstones which have a low F:C ratio, although it may weaken a positive criterion for beach sand.

Questions may be raised as to the wisdom of including all of the samples from a formation such as the Navajo sandstone or of the St. Peter sandstone, on the assumption that the entire formation was deposited under one environment. For instance, the Navajo may be in part marine, and in part eolian. If such be the case, more detailed work is necessary on each part; the present work is a

[5] Personal communication, 1944.

start. Perhaps the sands might have been sampled from sedimentation units[6] but the average field geologist will probably prefer the writer's method of sampling which simulated the taking of hand specimens and "average" material.

The need for many sand samples from the Gulf and Atlantic coasts is apparent. It is hoped that collections may be taken there after peace returns, and also from offshore sand which is more likely to become the marine sandstone of future geologic time.

A theoretical discussion of the causes of the size distribution of sand found in this investigation is postponed awaiting factual data on the sand from other coasts. Consequently, this paper is short—seemingly out of proportion to the time it took to collect the specimens and the long hours of sieving 781 samples of sand—but aside from presentation of the facts not much else need be written. The writer believes the F:C ratio procedure to be capable of much refinement, but even in its present form it helps differentiate some types of sand.

## FIELD AND LABORATORY PROCEDURE

In order that specific objectives might be attained, several precautions were observed in collecting and sieving the sands. Because it was intended to study both recent sand deposits and older sandstones (and possibly drill cores) on a comparable basis, samples of loose sand were collected from dunes and beaches to simulate, as closely as possible, hand specimens of sandstone. This was done by first scraping away the top inch or so of sand to avoid local surface effects, and then scooping out a large handful. The handful came from a depth of several inches—about the thickness of hand specimens broken from sandstone outcrops. In other words, had the dune or beach been consolidated and a hand specimen broken from the formation years afterward, it would have been similar to the loose sand taken now.

Beaches were sampled from the water's edge inland. Dunes were sampled from their windward sides, lee sides, along crests, across the dunes, in inter-dune depressions, and at regular intervals along a "Rosiwal traverse" across a dune area. The idea was to obtain a large number of samples which would average out the effect of any individual peculiarities.

The hand specimens taken from sandstone formations were broken from their outcrop at 5 to 9 foot intervals across the stratigraphic section. Only fresh rock was collected; the weathered exterior was first broken away. The St. Peter sandstone was sampled at four localities in Missouri: Foley, Mineola, Klondike, and Pacific. Specimens from the Tensleep formation were taken at the entrance to Sinks Canyon near Lander, Wyoming, and from the Wyopo several miles downstream. The Navajo was sampled below the long tunnel in Zion National Park, along the highway above the tunnel, and along a special fire-protection road leading to the top of the formation.

[6] George H. Otto, "The Sedimentation Unit and Its Use in Field Sampling," *Jour. Geol.*, Vol. 46 (1938), pp. 569–82.

It should be noted here that only "clean" sands and sandstones were examined in this investigation, that is, those without abundant carbonate, clay, or iron oxide cement. Some of the samples studied are rich in heavy minerals or in fairly fresh and hard silicate rock fragments, but materials like loess, adobe, or sand with abundant fossil or calcite particles were excluded from the study. At present the writer would apply the F:C ratio only to the "clean" varieties of sand.

In the laboratory, the sand specimen, or the sandstone which had been disaggregated with a wooden mortar and pestle, was split down to about a 100-gram sample and was sieved for 15 minutes through Tyler sieves on a Ro-Tap machine. Experiments showed that, under the conditions of the analysis, at least a 12-minute shaking time was necessary to give sieve percentages reproducible to within one per cent with prolonged sieving. The results of hand shaking are, in general, not considered reliable. Sieve fractions were recorded only to the nearest gram weight and to the nearest full per cent, because adjacent hand specimens in the field will usually vary as much as one per cent in some of their fractions (certainly so if the sandstone is cross-laminated).

No definite conclusion has been reached on the minimum number of specimens needed from a formation or locality to represent it, but certainly one or two grab samples can not be expected to furnish adequate F:C ratio data on a large body of sediment. Probably no less than a dozen samples should be collected from a small dune area or thin formation; a thorough study would necessitate abundant sampling throughout the entire occurrence.

ACKNOWLEDGMENTS

For the many hours of student labor used in sieving and assembling data the writer is indebted to NYA student assistance. The University Research Council of the University of Missouri furnished automobile expenses for travel during part of the summer of 1940 under Research Grant No. 109. Graduate and undergraduate students at the University of Missouri who have helped with the project include Roy L. Griggs, William C. Smith, Hal G. Stephens, Philip Williams, Robert Waldram, William E. Colson, Fred Strothmann, H. Hammond, and Joseph Burton. Mrs. W. A. Tarr, and Professors E. B. Branson and George H. Otto have read the manuscript. The superintendents and assistants of National and State parks were courteous and helpful in granting permission to sample and giving information while material was collected. The writer hereby expresses his indebtedness to all of those who so kindly helped him carry on this project.

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# GEOLOGICAL NOTES

## CRYSTALLINE ROCK IN A DEEP WELL IN WINKLER COUNTY, TEXAS[1]

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Lubbock, Texas

The Richardson and Bass J. B. Walton well No. 10-E, 1,980 feet from the south and east lines of Sec. 1, Block B-3, Public School Lands, Winkler County, Texas, was completed, April 16, 1944, at the total depth of 9,858 feet. Crystalline rock was encountered from 9,838 to 9,858 feet. A core was taken from 9,850 to 9,858 feet. The writer is indebted to the company through the district geologist, Morgan Gist, for the opportunity of examining samples of this core and for permission to publish the results of this examination.

Samples were furnished from depths of 9,850 to 9,858 feet.

Megascopic examination showed that these samples were of foliated metamorphic rock evidently derived from igneous rock. In order to determine their exact nature and origin, thin sections were made from the samples and studied under the petrographic microscope. A Rosiwal analysis was made of the thin sections and the rock was classified under the Johannsen system of igneous rocks. The results of this detailed examination are given below. In making the Rosiwal analysis use was made of a Wentworth recording micrometer and the standard number of traverses, 10, were run for each section. Determination of the plagioclase feldspar was made by the use of a Federoff universal stage.

### CORE FROM 9,850–9,851 FEET

*Megascopic.*—This core is of a distinctly foliated rock, the folia making an angle of 70°–80° with the axis of the core. Folia of biotite alternate with a slightly pinkish feldspar. Quartz is not as prominent a constituent as the feldspar.

*Microscopic.*—The rock consists of orthoclase which is greatly altered, showing much sericite, quartz which shows undulatory extinction, brown biotite, fairly numerous flakes of magnetite, a few crystals of apatite, and a few anhedral crystals of garnet. Some crystals of secondary calcite occur. These were not included in the Rosiwal analysis.

### CORE FROM 9,852–9,853 FEET

*Megascopic.*—This rock is distinctly foliated, the folia making an angle of 70°–80° with the axis of the core. Alternating folia are of slightly pinkish feld-

[1] Manuscript received, November 30, 1944.

[2] Head of department of geology and petroleum engineering, Texas Technological College.

ROSIWAL ANALYSIS

(Millimeters)

| *Traverse* | *Orthoclase* | *Quartz* | *Biotite* | *Magnetite* | *Garnet* |
|---|---|---|---|---|---|
| 1 | 7.900 | 5.850 | 1.345 | 0.340 | |
| 2 | 9.730 | 2.620 | 1.837 | | |
| 3 | 8.625 | 3.450 | 1.590 | | |
| 4 | 8.260 | 3.235 | 2.590 | | 0.055 |
| 5 | 9.810 | 3.810 | 2.810 | 0.525 | |
| 6 | 10.420 | 3.090 | 2.300 | | |
| 7 | 9.070 | 4.865 | 2.600 | 0.240 | 0.140 |
| 8 | 8.900 | 3.500 | 3.300 | 0.195 | 0.140 |
| 9 | 10.945 | 3.240 | 3.170 | | |
| 10 | 10.005 | 3.565 | 3.085 | | |
| | 94.665 | 37.225 | 24.627 | 1.300 | 0.335 |

PERCENTAGE COMPOSITION

Orthoclase = 60.0
Quartz = 23.2
Biotite = 15.6
Magnetite = 0.8
Garnet = 0.3

99.9

Leucocrates are 83 per cent of the total components — Class 2
No plagioclase — Order 1
Quartz is 39 per cent of total quarfeloids
Orthoclase is 100 per cent of the feldspars — Family 5
Rock No. 215 is kaligranite

spar, biotite, and some quartz. The texture is somewhat coarser than that of specimen from 9,850–9,851 feet. Some veins of calcite are present.

ROSIWAL ANALYSIS

(Millimeters)

| *Traverse* | *Orthoclase* | *Quartz* | *Biotite* |
|---|---|---|---|
| 1 | 5.431 | 2.775 | 1.015 |
| 2 | 7.310 | 1.135 | 2.240 |
| 3 | 4.210 | 4.160 | 0.650 |
| 4 | 3.748 | 2.110 | 1.140 |
| 5 | 6.555 | 1.685 | 1.185 |
| 6 | 7.305 | 1.640 | 1.220 |
| 7 | 7.110 | 2.015 | 0.535 |
| 8 | 5.190 | 3.170 | 0.770 |
| 9 | 3.475 | 3.960 | 1.615 |
| 10 | 5.020 | 2.270 | 0.415 |
| | 55.326 | 24.910 | 8.785 |

PERCENTAGE COMPOSITION

Orthoclase = 62.5
Quartz = 27.9
Biotite = 9.6

100.0

Leucocrates form 90 per cent of total components — Class 2
No plagioclase present — Order 1
Quartz is 30 per cent of total quarfeloids
Orthoclase is 100 per cent of total feldspars — Family 5
Rock No. 215 is kaligranite

*Microscopic.*—The minerals consist of orthoclase, quartz, and brown biotite. The orthoclase is greatly altered, showing much sericite. The quartz shows undulatory extinction. A few crystals of apatite and a few grains of magnetite are present.

CORE FROM 9,854–9,855 FEET

*Megascopic.*—This core is of crystalline rock showing rougher foliation than the two preceding samples. The folia make an angle of 70°–80° with the axis of the core. Feldspar is a prominent constituent, and folia of biotite are prominent. Quartz is less conspicuous.

*Microscopic.*—The rock is made up of orthoclase, andesine, brown biotite, and quartz. A few crystals of magnetite are scattered through the section. A few crystals of zircon showing pleochroic halos are seen in the biotite. Both the orthoclase and the andesine are very little altered, which is in marked contrast with the preceding samples.

ROSIWAL ANALYSIS

(Millimeters)

| *Traverse* | *Orthoclase* | *Andesine* | *Biotite* | *Quartz* | *Magnetite* |
|---|---|---|---|---|---|
| 1 & 2 | 8.830 | 1.221 | 6.000 | 6.425 | |
| 3 | 4.010 | 0.000 | 8.225 | 2.075 | |
| 4 | 6.875 | 2.175 | 6.575 | 0.135 | 0.190 |
| 5 | 3.615 | 2.225 | 5.480 | 2.770 | |
| 6 | 5.410 | 3.760 | 3.500 | 0.000 | |
| 7 | 8.200 | 0.550 | 2.650 | 1.090 | 0.320 |
| 8 | 8.975 | 0.650 | 3.075 | 0.075 | |
| 9 | 4.410 | 1.650 | 3.660 | 3.090 | |
| 10 | 6.400 | 0.000 | 4.010 | 0.000 | |
| | 52.725 | 12.231 | 43.175 | 15.660 | 0.510 |

PERCENTAGE COMPOSITION

Orthoclase = 45.7
Andesine = 10.6
Biotite = 37.3
Quartz = 5.7
Magnetite = 0.4

99.7

Leucocrates form 71 per cent of total components — Class 2
Plagioclase is andesine — Order 2
Quartz is 9.5 per cent of total quarfeloids
Orthoclase is 82 per cent of total feldspars — Family 6
Rock No. 226 is granite

CORE FROM 9,856–9,857 FEET

*Megascopic.*—This core exhibits rough foliation, the folia making about the same angle with the axis of the core as in the preceding samples. The core is cut by small fractures filled with hematite. Feldspar is the most prominent mineral.

*Microscopic.*—The section contains much orthoclase which has been very greatly altered, showing much sericite. The section also shows a few small hematite veins. Hematite was not included in the analysis. Biotite has been largely altered to chlorite, which varies from light green to almost colorless.

ROSIWAL ANALYSIS

(Millimeters)

| *Traverse* | *Orthoclase* | *Quartz* | *Biotite (Chlorite)* |
|---|---|---|---|
| 1 | 5.624 | 2.210 | 0.960 |
| 2 | 4.865 | 3.305 | 0.665 |
| 3 | 4.310 | 2.440 | 0.820 |
| 4 | 3.710 | 2.330 | 1.510 |
| 5 | 4.710 | 3.430 | 0.560 |
| 6 | 6.470 | 2.210 | 0.710 |
| 7 | 2.875 | 2.650 | 0.910 |
| 8 | 3.510 | 1.585 | 1.365 |
| 9 | 6.035 | 2.330 | 1.050 |
| 10 | 2.535 | 1.555 | 1.355 |
| | 44.645 | 24.045 | 9.905 |

PERCENTAGE COMPOSITION

Orthoclase = 56.7
Quartz = 30.6
Biotite = 12.6

99.9

Leucocrates form 87 per cent of total components — Class 2
No plagioclase — Order 1
Quartz is 35 per cent of quarfeloids
Orthoclase is 100 per cent of total feldspar — Family 5
Rock No. 215 is kaligranite

CORE FROM 9,857–9,858 FEET

*Megascopic.*—The core from this depth is a foliated rock showing feldspar,

ROSIWAL ANALYSIS

(Millimeters)

| *Traverse* | *Orthoclase* | *Quartz* | *Biotite (Chlorite)* |
|---|---|---|---|
| 1 | 10.265 | 8.480 | 0.905 |
| 2 | 11.927 | 4.815 | 1.695 |
| 3 | 10.725 | 4.195 | 0.300 |
| 4 | 8.790 | 6.880 | 0.750 |
| 5 | 11.005 | 5.795 | 1.550 |
| 6 | 9.525 | 8.240 | 1.060 |
| 7 | 10.055 | 6.010 | 1.390 |
| 8 | 11.005 | 6.300 | 0.820 |
| 9 | 9.875 | 5.010 | 2.710 |
| 10 | 7.475 | 4.110 | 2.980 |
| | 100.651 | 59.840 | 14.210 |

PERCENTAGE COMPOSITION

Orthoclase = 57.7
Quartz = 34.2
Biotite = 8.1

Leucocrates form 91 per cent of total components — Class 2
No plagioclase — Order 1
Quartz is 37 per cent of total quarfeloids
Orthoclase is 100 per cent of total feldspars — Famil
Rock No. 215 is kaligranite

biotite, and quartz. In part of the core the biotite has been altered to chlorite and its green color is prominent.

*Microscopic.*—Thin sections, taken in the part showing alterations of biotite to chlorite, show that the biotite has been almost completely altered to chlorite. In a thin section, taken in the unaltered part, brown biotite is prominent. The rock contains the following minerals: orthoclase greatly altered, showing much sericite; quartz; biotite; and chlorite derived from biotite. The chlorite varies from pale green to almost colorless. Rosiwal analysis taken in the part in which the biotite shows alterations to chlorite.

### DISCUSSION OF RESULTS

Except for the sample from 9,854–9,855 feet, all the analyses are similar and indicate a derivation from kaligranite. The sample from 9,854–9,855 feet differs from the others in that the feldspars are much less altered, and in the presence of plagioclase. The analysis of this sample indicates derivation from a normal granite. However, all analyses indicate derivation from granitic rock.

The foliation of the specimens varies somewhat and is more perfect than found in some gneisses. Because of the relative abundance of feldspar, however, the rocks would properly be classed as gneisses. Because of a relatively large amount of biotite or its alteration product, they would be classed as biotite granite gneisses.

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## RUSTON GAS FIELD, LINCOLN PARISH, LOUISIANA[1]

H. R. KAMB[2]
Shreveport, Louisiana

The discovery of commercial gas in the Arkansas-Louisiana Gas Company's W. F. Jiles No. 1, Sec. 19, T. 19 N., R. 2 W., Lincoln Parish, Louisiana, in October, 1943, marked the culmination of a number of years of exploration effort by the Arkansas-Louisiana Gas Company and the Arkansas Fuel Oil Company, subsidiaries of the Arkansas Natural Gas Corporation. The new field is variously termed Vienna, North Ruston, and Ruston. Ruston is the name most frequently used and it is favored by the writer.

The first work that led to the finding of the new gas reserve was surface mapping of an anticline. A check was made with reflection seismograph and the top of the structure was found to shift northwest with depth. The first well on the prospect, the Arkansas-Louisiana Gas Company *et al.*, M. E. Causey No. 1, Sec. 32, T. 19 N., R. 2 W., found gas and salt water in a sand from 5,315 to 5,340 feet at the base of the Pine Island formation, but diligent efforts to complete it as a

[1] Manuscript received, December 22, 1944. Published with the permission of the Arkansas Natural Gas Corporation.

[2] Geologist, Arkansas Natural Gas Companies.

commercial well were unavailing. Subsequently, after additional detailing by reflection seismograph, the second test, the Arkansas-Louisiana Gas Company's W. F. Jiles No. 1, was successful and was completed on October 26, 1943. Its initial estimated gauge was 45 million cubic feet of dry gas per day in a sand of the Hosston (Travis Peak) formation.

In all, apparently six productive sands have been found to date. All are lenticular. Enumerated in descending order, the first lies on top of, or is part of, the James formation. If the latter, it is of interest because it marks the first commercial production ever found in the James. A drill-stem test in the Jiles No. 1, where the sand was encountered from 4,738 to 4,762 feet, indicated a flow of 50 million cubic feet per day of dry gas. The second is the sand previously mentioned as lying at the base of the Pine Island formation and has been termed the Causey. It is producing gas in the Arkansas-Louisiana Gas Company's J. C. Dowling No. 1, Sec. 30, T. 19 N., R. 2 W., and, so far as known to the writer, is the first commercial production in the Pine Island. In this well, the sand is at 5,190–5,205 feet. A third sand, encountered 25–30 feet below the top of the Sligo formation (commonly called Pettit by many geologists), has been termed the Dowling after the well noted immediately above and in which it produces from 5,264 to 5,278 feet. A fourth sand, found from 5,366–5,375 feet in the Arkansas-Louisiana Gas Company's Mitchell Unit No. 1, Sec. 20, T. 19 N., R. 2 W., and lying close to the base of the Sligo formation, is unnamed. It is noteworthy that the porous sand lenses in the Sligo formation reveal a regional gradation from limestone to sand eastward updip in North Louisiana. A fifth sand, termed the Mitchell after the first well in it, was topped at 5,724 feet or approximately 325 feet below the top of the Hosston formation. The sixth has been named the Jiles and was reached 485 feet below the top of the Hosston or from 5,878 to 5,922 feet in the well with that name. All the gas produced to date has been dry and goes directly into the pipeline without processing.

The structure is anticlinal and probably of the deep-seated salt-uplift type. Producing closure appears to be from 65 to 80 feet on top of the Hosston. The total productive area is not entirely defined, but presently appears to approximate 4,000 acres. Development is on the basis of one well per 640-acre unit.

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## RECENT DEEP TEST IN MOORE COUNTY, TEXAS[1]

E. W. FOSSHAGE[2]
Amarillo, Texas

The Shamrock Oil and Gas Corporation and the Phillips Petroleum Company commenced drilling a deep test, the Shamrock acting as operator, on March 3, 1944, in Sec. 11, Block 1, J. Poitevent Survey, Moore County, Texas. After some

[1] Manuscript received, January 5, 1945.

[2] Geologist, Shamrock Oil and Gas Corporation.

drilling difficulties, which included a fishing job at the depth of 2,711 feet, the bit had penetrated 380 feet of the Arbuckle limestone group at the total depth of 6,706 feet on October 10, 1944. Because no commercial oil or gas showings were encountered below the Permian dolomite, this test was plugged back to 2,924 feet after an electrical survey of the formations was made. At this plug-back depth it will be completed as a gas well in the Permian dolomite, which is the normal producing zone in the Texas Panhandle.

The writer is grateful to C. C. Hemsell, chief geologist of the Shamrock Oil and Gas Corporation, and to the management of this company for permission to publish the geological data on this test. It is hoped that these data will encourage additional deep drilling in this area, which has been explored very little for oil in pre-Permian strata. The presence of pre-Permian reservoir rocks and the somewhat complicated structural conditions are the favorable factors for pre-Permian oil possibilities in the Texas Panhandle.

Correlations of the pre-Permian formations encountered in the Taylor well No. 2 are very difficult because of the limited information about these rocks in this Tarea. he following are the writer's own determinations and correlations of these formations, which may not necessarily be in agreement with determinations made by other geologists.

| | *Feet* |
|---|---|
| Derrick-floor elevation | 3,328 |
| Top of thickness of geological unit | |
| Tertiary system | Surface |
| Ogallala formation | 0– 371 |
| Permian system | |
| Guadalupe series | |
| Whitehorse sandstone and shale | 371 |
| Leonard series | |
| Blaine gypsum | 645 |
| Glorieta sandstone | 1,015 |
| Clear Fork group | 1,073 |
| Cimarron anhydrite | 1,443–1,517 |
| "Panhandle lime" | 2,310 |
| (Approximately Wellington or Wichita-Albany groups) | |
| "Brown dolomite" | 2,558 |
| (Principal oil and gas producing zone in Texas Panhandle) | |
| (Top is approximately Herington in age. Lower part is Wolfcamp in age) | |
| Wolfcamp series | |
| "Moore County white lime" | 2,758 |
| Permian-Pennsylvanian systems | ? |
| Subdivision of lower Permian and all of Pennsylvanian rocks into formations or series names can not be done accurately without paleontological data, which, in this case, would be mainly fusulinid determinations. As this information is not available at present, it is not given | |
| "Granite wash," shale, and limestone | 3,640 |
| Mississippian system | 5,530 |
| Iowa series | 5,530 |
| Meramec group | 5,530 |
| Osage group | 5,814 |
| Kinderhook group | 6,035 |
| (Composed mainly of coarse clastics and thought to be a facies change of Kinderhook shale of Oklahoma and Kansas) | |
| Devonian-Silurian systems | 6,160 |
| Hunton limestone group | 6,160 |

| | |
|---|---|
| Ordovician system | |
| Viola limestone group | 6,212 |
| Simpson group | 6,260 |
| Ordovician-Cambrian systems | 6,330 |
| Arbuckle limestone group | 6,330 |
| Mostly tight magnesian limestone | 6,330–6,565 |
| Porous magnesian limestone | 6,565–6,706 |
| Total depth | 6,706 |

The top of the Mississippian system is not correlated the same by all geologists. The zone from 5,200 to 5,530 feet contains many Mississippian-type limestones, together with "granite wash" and conglomeratic material. The writer had the advantage of being at this test while it was drilled, and the drilling reaction indicated that the interval from 5,200 to 5,530 feet is a conglomeratic zone. The self-potential curve on the Schlumberger electric log shows low porosity in this zone, which suggests a conglomerate with a shale matrix. For these reasons the writer has placed the top of the Mississippian system at 5,530 feet and has interpreted the Mississippian-type limestones from 5,200 to 5,530 feet as reworked.

The Hunton and Viola limestones in this test are lithologically similar to their equivalents in Oklahoma. An unconformity sandstone separates these two units in this test.

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# REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

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## GEOLOGY IN THE SERVICE OF MAN, BY W. G. FEARNSIDES AND O. M. B. BULMAN

REVIEW BY BURTON WALLACE COLLINS[1]
Auckland, New Zealand

*Geology in the Service of Man*, by W. G. Fearnsides and O. M. B. Bulman. 158 pp., 8 pls., 38 figs. Penguin Books, Harmondsworth, England, and New York, U.S.A. (1944).

Members of the geological profession owe a debt of gratitude to the authors of this recent "Penguin" book on two counts. Many will find it not only very readable but also stimulating. And the profession as a whole can not fail to benefit from the publicity that it will obtain from the wide circulation that the book will undoubtedly receive—its own intrinsic merit, the reputation of its authors and publishers, and its ridiculously low price (ninepence in England) may well combine to make this pocket compendium to applied earth-science a geological best-seller comparable with, if not outshining, the works of Sir Charles Lyell and Hugh Miller.

A statement in the preface with which most geologists will no doubt agree is: "It is regretable that more geologists have not been professionally associated with the war effort; it will be a tragedy if geological knowledge is not co-ordinated and directly applied in post-war reconstruction." The book should do much to correct the present tendency to overlook or ignore the contribution which geology is ready to make to world order,[2] as well as help to place geological publicity in general more on a par with that of the chemical and physical sciences. It should also stimulate amateur interest in the science—an interest which appears to have flagged somewhat lately though at one time very strong. In the words of the preface again: "There is no other science, except perhaps astronomy, to which the amateur observer has contributed so much."

Avowedly written for "the layman, the industrialist, and the schoolmaster," this book yet contains much that will interest the trained geologist, and almost certainly some things that will be entirely new to him. Its first part (pp. 11–76) is entitled "The Nature of the Evidence: An Introduction to the Principles of Geology." Here are discussed the nature of the earth's crust, types of rocks, sedimentation, earth movements, mountain-building, erosion in its various aspects, *et cetera*. There is also an "Epitome of the Geological History of Britain" (Chapter IV), with four paleogeographic maps, which compresses much into its 17 pages; and a section on "The Construction and Use of Geological Maps" (Chapter V), with particular reference to the maps issued by the Geological Survey of Great Britain, and including a brief discussion of structural contours.

Part Two, "Some Applications of Geology," comprises the remainder of the book (pp. 77–149). The chapter headings are: "The Geology of Water Supply," "Geology and Soils," "The Geology of Petroleum," "Engineering Geology," "Mineral Supplies for Heavy Industries," "Nonferrous Metals and Chemical Supplies," and "Gemstones."

The chapter on petroleum geology, though very brief (only 4½ pages of text and one

[1] P. O. Box 10, Auckland, New Zealand. Review received, December 24, 1944.

[2] See, for example: C. K. Leith, J. W. Furness, and Cleona Lewis, *World Minerals and World Peace*, 253 pp., maps and tables. The Brookings Institution, New York (1943).

figure), covers much ground—theories of origin, source rock, reservoir rock and cap rock, structural traps (the figure shows sections of three common types of traps—anticline, fault, and unconformity), and geological and geophysical methods of prospecting. One could wish that a little more space had been allotted to this important application of geology, especially at the present time when the question of oil supplies bulks so largely on the world's economic horizon. Americans at least may feel rather dissatisfied with the treatment accorded what is peculiarly an American industry, but after all the book was written by Englishmen, apparently primarily *for* Englishmen, who are naturally more at home with coal and iron (10 pages) than with oil.

Under engineering geology are discussed foundations, surface creep and landslides, water-supply reservoirs, tunnels (with a most interesting account of geological work for the new Mersey tunnel), building stone, clays and brick-making, cements, roofing slate, and road metal.

Mineral deposits in general are described in the chapter on non-ferrous metals and chemical supplies. Each of the following materials is then discussed separately, with references to its composition, ores, extraction, geologic occurrence, geographic distribution, uses, *et cetera:* gold, silver, platinum, copper, lead and zinc, nickel, cobalt, chromium, tin, tungsten, molybdenum, manganese, mercury, aluminium, magnesium, saline deposits, phosphates, sulphur, and pyrites.

The book concludes with appendices containing tabular classifications of igneous and sedimentary rocks, and the geological systems and formations of Great Britain, a list of suggestions for further reading (books only, mainly English publications but also five American works—and including, it may be worth noting, the New Zealand Professor Cotton's recent book on geomorphology, *Landscape*, which was reviewed in this *Bulletin* for July, 1943), and a 3-page double-column index.

The figures—mainly geological sections, with some block diagrams and maps—greatly enhance the book's value and interest, while the collogravure plates are beautifully reproduced and worth in themselves the price of the book. They show: microphotographs of typical rocks, the Matterhorn showing recumbent fold, Grand Canyon, sea-stack on Caithness coast, Venangyaung oil field, North Wales slate quarry, coal face in a Yorkshire mine, and open-cast mining of iron ore in Northamptonshire.

It is an odious part of the reviewer's duty to point out possible faults. In the case of the present book to do so is like looking a gift horse in the mouth. Two points may be mentioned, however. The use of technical terms without definition is to be deprecated in a book intended for lay readers. Another reviewer has already suggested that a glossary would be a useful addition to a subsequent edition, and this view may be heartily endorsed. Secondly, the scant mention of fossils is curious, especially when one considers that one of the authors (Bulman) is outstanding as a paleontologist—the other (Fearnsides) is the present president of the Geological Society of London and an expert in economic geology. Fossils are mentioned in passing in a few places (for instance, in the chapter on petroleum geology as an aid in correlation, and *Iguanodon* and *Globigerina* are referred to in the chapter on the geological history of Britain), but the word does not even find a place in the index—nor does paleontology. One could have wished that a little more space could have been devoted to what after all is basic to all geological history, much correlation, and a considerable part of geological mapping, even if such a course meant reducing the number of pages on some other topic (for example, gemstones, with their 11 pages, not all strictly geology as generally conceived).

One error of fact was noted. In discussing nickel (p. 130) the authors mention that New Caledonia was at one time (actually until 1905) the world's chief source. They then state: "Mines there continued to produce their quota . . . till the region was overrun by the Japanese." As many Americans will know, and as all New Zealanders and Australians have very good reasons for knowing, New Caledonia was, of course, never overrun by the

Japanese; and, in fact, the nickel and chrome mines have continued in full production—for the Allies, since New Caledonia, together with its sister colony the French Establishment of Oceania (Tahiti), from the outset declared for Free France.

Finally, this book may be confidently recommended as suitable (and inexpensive enough) to be bought by the dozen (if they can obtain it in such quantities—the supply in New Zealand is so short that this review is being written with a borrowed copy) by busy geologists for placing in the hands of those well meaning friends who enquire: "What is the *use* of geology, anyway?"

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## STRATIGRAPHY OF THE COLORADO GROUP, UPPER CRETACEOUS, IN NORTHERN NEW MEXICO, BY CHARLES H. RANKIN

REVIEW BY W. A. WALDSCHMIDT[1]
Midland, Texas

"Stratigraphy of the Colorado Group, Upper Cretaceous, in Northern New Mexico," by Charles H. Rankin. *New Mexico State Bur. Mines and Min. Resources Bull. 20* (Socorro, New Mexico, 1944). 27 pp., 6 figs. Price, 25 cents.

Described in this publication are 6 sections of the Greenhorn limestone and 11 sections of the Colorado group (Niobrara to Dakota formations) which were measured in northern New Mexico and southern Colorado.

The author has introduced the name "Juana Lopez" for a calcareous sandstone member of the Carlile shale. The type section of this member is west of Cerrillos, in the Mesita Juana Lopez Grant, Santa Fe County, New Mexico. Because fossils of Frontier age are abundant in the Juana Lopez sandstone, it might be advisable to consider it as a tongue of the Frontier.

In addition to discussing the correlations of the measured sections and giving a short summary of the historical geology of the region, the author has illustrated graphically, on 4 plates, the relationships of the formations and members of the Colorado group.

This publication should be of value and interest to geologists engaged either in field work or subsurface studies in Colorado and New Mexico.

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## RECENT PUBLICATIONS

### CANADA

*"Cretaceous Formations in Canada," by G. S. Hume, *Oil Weekly*, Vol. 116, No. 4 (December 25, 1944), pp. 36–42; 3 figs.

### GENERAL

*"The Future of Oil Finding," by Paul D. Krynine. *Mineral Industries*, Vol. 14, No. 2 (Pennsylvania State College, State College, Pennsylvania, November, 1944), pp. 1–3; 1 fig.

"Supplement to Catalogue of Mesozoic and Cenozoic Plants of North America, 1919–37," by R. S. LaMotte. *U. S. Geol. Survey Bull. 924* (November, 1944). 330 pp. For sale by Supt. Documents, Govt. Printing Office, Washington 25, D. C. Price, $0.40.

*"Abstracts," of the annual meetings of the Geological Society of America, the

[1] Review received, December 15, 1944.

Paleontological Society, and Section E of the American Association for the Advancement of Science. *Bull. Geol. Soc. America*, Vol. 55, No. 12 (December, 1944), pp. 1463–86.

**Oil Zones of Southern U.S.A., Mexico, Caribbean, South America*, prepared by Seismograph Service Corporation of Delaware. *Oil and Gas Jour.*, Vol. 43, No. 34 (Tulsa, December 30, 1944), pp. 182–99; 9 maps in color; 9 stratigraphic correlation charts. Also privately printed as a 22-page booklet by Seismograph Service Corporation, Tulsa, Oklahoma. Maps show depositional areas of major sedimentary geological systems, location of oil fields, and indication of oil possibilities.

*"Characteristics of Reservoirs," by Park J. Jones. *Oil and Gas Jour.*, Vol. 43, No. 35 (Tulsa, January 6, 1945), pp. 49–53; 6 figs. Part 10 of a series.

JAMAICA

* "Notes on the Foraminifera from Bowden, Jamaica," by Dorothy K. Palmer. *Bulletins of Amer. Paleon.*, Vol. 29, No. 115 (Paleontological Research Institution, Ithaca, New York, January 3, 1945). 82 pp., 2 pls.

MISSOURI AND ARKANSAS

*"The Stratigraphy of Some Lower Ordovician Formations of the Ozark Uplift," by James S. Cullison. *Univ. Missouri School of Mines and Metallurgy Bull. Tech. Ser.*, Vol. 15, No. 2 (Rolla, June, 1944). 112 pp., 24 half-tone and full-tone, 10 folded line pls. Free.

NEW MEXICO

"Geologic Map and Stratigraphic Sections of Permian and Pennsylvanian Rocks of Parts of San Miguel, Santa Fe, Sandoval, Bernalillo, Torrance, and Valencia Counties, North-Central New Mexico," by C. B. Read *et al. U. S. Geol. Survey Prelim. Map 21*, Oil and Gas Inves. Ser. (January 17, 1945). Single sheet, 40×55 inches. Scale, 1 inch equals 3 miles. Contains 3 structure sections, 4 groups of stratigraphic sections, 2 maps showing thicknesses of some of the formations, text summarizing stratigraphy and oil and gas possibilities, and a list of wells.

NORTH DAKOTA

*"Stratigraphy and Structure of North Dakota," by Wilson M. Laird. *North Dakota Geol. Survey Bull. 18* (Grand Forks, 1944). 11 pp. reprinted from National Oil Scouts and Landmen's Association *Yearbook*, Vol. 14 (1944), pp. 420–30; 5 figs.

PENNSYLVANIA

"Oil-Bearing Sands in Southwestern Pennsylvania," by Matteson and Busch. *Pennsylvania Top. and Geol. Survey Spec. Bull. 1* (Harrisburg, January, 1945). For sale by Division of Documents, Department of Property and Supplies, 10th and Market Streets, Harrisburg. Price, $1.50.

TEXAS

*"Progress Report on the Ground-Water Resources of the Houston District," by N. A. Rose and W. H. Alexander, Jr. *Texas State Board of Water Engineers*. Prepared in cooperation with the U. S. Geological Survey and the City of Houston (November, 1944). 37 mim. pp., 8.5×11 inches. 12 figs.

VIRGINIA

"Map of the Rose Hill Oil Field, Virginia." *U. S. Geol. Survey Prelim. Map 20*, Oil and Gas Inves. Ser. (January, 1945). For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.50.

WYOMING

"Map of Wyoming Showing Test Wells for Oil and Gas, Anticlinal Axes, and Oil and Gas Fields," by H. H. R. Sharkey, J. D. Love, and Jewell Kirby. *U. S. Geol. Survey Prelim. Map 19*, Oil and Gas Investig. Ser. (December, 1944). For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.50.

WYOMING-MONTANA

"Geologic and Structure Map of Elk Basin Oil and Gas Field and Vicinity, Park County, Wyoming, and Carbon County, Montana," by C. E. Dobbin, W. B. Kramer, J. C. Miller, and W. C. Senkpiel. *U. S. Geol. Survey Prelim. Map 19*, Oil and Gas Inves. Ser. (January, 1945). For sale by Director, U. S. Geological Survey, Washington 25, D. C. Price, $0.25.

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ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 14, No. 3 (December, 1944)

"Grain Analyses of Minerals of Sand Size in Ball Mills," by Harold L. Alling

"Deposition of Sediment in Pool No. 15 at Rock Island, Illinois," by Troy L. Pewe

"Red River Mineral Provenance, Taos County, New Mexico," by Raymond Sidwell and Charles A. Renfroe

Heavy Mineral Correlation of the Fox Hills, Hell Creek, and Cannonball Sediments, Morton and Sioux Counties, North Dakota," by Marie Louise Lindberg

"An Interesting Mississippian Breccia," by John W. Frink

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 19, No. 7, January, 1945.

"North American Cymatoceratidae (Mesozoic Nautiloidea)," by A. K. Miller and Robert A. Harris

"Some Exceptional Permian Ammonoids from West Texas," by A. K. Miller

"A Permian Ammonoid from Sonora," by A. K. Miller

"A New Sauropod Dinosaur from the Upper Cretaceous of Missouri," by Charles W. Gilmore and Dan R. Stewart

"A New Eocene Lizard from Wyoming," by Charles W. Gilmore and Glenn L. Jepsen

"The Biostratigraphy of *Glycymeris veatchii* in California," by Clay T. Smith

"The Cretaceous Flora from the Pantou Series in Yungan, Fukien," by H. C. Sze

"An Occurrence of Late Pleistocene Mammals in the San Francisco Peninsula," by Frank E. Peabody

"Silurian Fossils from Ripogenus Dam, Maine," by Bradford Willard

"The Thorax of *Terataspis*," by Irving G. Reimann

"A New Upper Cretaceous Oyster from Deep Wells in Mississippi," by Lloyd William Stephenson

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| H. E. MINOR | A. C. WRIGHT | K. K. SPOONER |
| | | T. E. WEIRICH |

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WINTHROP P. HAYNES (1945), *vice-chairman*, 30 Rockefeller Plaza, New York

| 1945 | 1946 | 1947 |
|---|---|---|
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| RONALD K. DEFORD | ALFRED H. BELL | ROLAND F. BEERS |
| M. G. EDWARDS | WALTER R. BERGER | G. C. GESTER |
| MARSHALL KAY | PAUL E. FITZGERALD | STUART E. BUCKLEY |
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| A. I. LEVORSEN | RALPH A. LIDDLE | S. W. LOWMAN |
| TOM MCGLOTHLIN | W. H. TWENHOFEL | D. PERRY OLCOTT |
| | F. M. VAN TUYL | JOSEPH A. SHARPE |

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| 1945 | 1946 | 1947 |
|---|---|---|
| ROBERT I. DICKEY | GORDON I. ATWATER | STUART K. CLARK |
| HUGH D. MISER | DARSIE A. GREEN | ROY T. HAZZARD |
| RAYMOND C. MOORE | RALPH W. IMLAY | W. J. HILSEWECK |
| NORMAN L. THOMAS | HORACE D. THOMAS | WAYNE V. JONES |
| | C. W. TOMLINSON | W. ARMSTRONG PRICE |

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| 1945 | 1946 | 1947 |
|---|---|---|
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| CECIL H. GREEN | J. BRIAN EBY | THOMAS A. HENDRICKS |
| M. M. LEIGHTON | H. S. MCQUEEN | KENNETH K. LANDES |
| R. B. RUTLEDGE | R. A. STEINMAYER | |

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WILLIAM M. RUST, JR., *ex officio*, president of S.E.G.

| 1945 | 1946 | 1947 |
|---|---|---|
| G. CLARK GESTER | FRANK R. CLARK | H. B. FUQUA |
| DARSIE A. GREEN | RAYMOND F. BAKER | THORNTON DAVIS |
| WALLACE C. THOMPSON | JAMES A. MACDONELL | HUGH D. MISER |

## NATIONAL SERVICE COMMITTEE

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| A. E. BRAINERD | M. GORDON GULLEY | MORRIS M. LEIGHTON |
| GEORGE M. CUNNINGHAM | W. DOW HAMM | PHIL F. MARTYN |
| THORNTON DAVIS | WINTHROP P. HAYNES | DEAN A. MCGEE |
| RONALD K. DEFORD | W. B. HEROY | CLARENCE L. MOODY |
| A. RODGER DENISON | HAROLD W. HOOTS | |

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## COMMITTEE ON SOUTH AMERICAN GEOLOGY

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## COMMITTEE ON CODE OF ETHICS

C. W. TOMLINSON, *chairman*, 509 Simpson Building, Ardmore, Oklahoma

RAYMOND F. BAKER ORVAL L. BRACE HAROLD W. HOOTS T. S. HARRISON

## COMMITTEE ON METHOD OF ELECTION OF OFFICERS

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RONALD K. DEFORD JOHN S. IVY C. L. MOODY
W. DOW HAMM HUGH D. MISER EARL B. NOBLE

## PAST AND PRESENT OFFICERS OF THE ASSOCIATION

| *Elected In* | *At* | *President* | *Vice-President*[1] | *Secretary-Treasurer*[2] | *Editor*[3] |
|---|---|---|---|---|---|
| 1917 | Tulsa | J. Elmer Thomas | Alex. Deussen | M. G. Mehl | C. H. Taylor |
| 1918 | Oklahoma City | Alex. Deussen | I. C. White[4] | W. E. Wrather | C. H. Taylor |
| 1919 | Dallas | I. C. White[4] | Irving Perrine | C. E. Decker | C. H. Taylor |
| 1920 | Dallas | W. E. Pratt | Alex. W. McCoy[6a] | C. E. Decker | R. C. Moore |
| 1921 | Tulsa | G. C. Matson[5] | G. C. Gester | C. E. Decker | R. C. Moore |
| 1922 | Oklahoma City | W. E. Wrather | Max W. Ball | C. E. Decker | R. C. Moore |
| 1923 | Shreveport | Max W. Ball | F. W. DeWolf | C. E. Decker | R. C. Moore |
| 1924 | Houston | J. H. Gardner | E. G. Gaylord | C. E. Decker | R. C. Moore |
| 1925 | Wichita | E. L. DeGolyer | R. S. McFarland | C. E. Decker | R. C. Moore |
| 1926 | Dallas | Alex. W. McCoy[6a] | C. R. McCollom | Fritz L. Aurin | J. L. Rich |
| 1927 | Tulsa | G. C. Gester | Luther H. White | David Donoghue | J. L. Rich |
| 1928 | San Francisco | R. S. McFarland | J. E. Elliott | David Donoghue | J. L. Rich |
| 1929 | Fort Worth | J. Y. Snyder[6] | Fred H. Kay[7] | A. R. Denison | F. H. Lahee |
| 1930 | New Orleans | Sidney Powers[8] | Ralph D. Reed[9] | Marvin Lee | F. H. Lahee |
| 1931 | San Antonio | L. P. Garrett[10] | L. C. Decius | Frank R. Clark | F. H. Lahee |
| 1932 | Oklahoma City | F. H. Lahee | R. J. Riggs | W. B. Heroy | R. D. Reed[9] |
| 1933 | Houston | Frank R. Clark | George Sawtelle | W. B. Heroy | L. C. Snider |
| 1934 | Dallas | W. B. Heroy | E. B. Hopkins[11] | M. G. Cheney | L. C. Snider |
| 1935 | Wichita | A. I. Levorsen | F. A. Morgan | E. C. Moncrief | L. C. Snider |
| 1936 | Tulsa | Ralph D. Reed[9] | C. E. Dobbin | Chas. H. Row | L. C. Snider |
| 1937 | Los Angeles | H. B. Fuqua | C. L. Moody | Ira H. Cram | W. A. Ver Wiebe |
| 1938 | New Orleans | D. C. Barton[12] | H. W. Hoots | Ira H. Cram | W. A. Ver Wiebe |
| 1939 | Oklahoma City | Henry A. Ley | L. M. Neumann | Ed. W. Owen | W. A. Ver Wiebe |
| 1940 | Chicago | L. C. Snider | John M. Vetter | Ed. W. Owen | W. A. Ver Wiebe |
| 1941 | Houston | Ed. W. Owen | Earl B. Noble | E. O. Markham | W. A. Ver Wiebe |
| 1942 | Denver | F. L. Aurin | Paul Weaver | E. O. Markham | W. A. Ver Wiebe |
| 1943 | Fort Worth | A. R. Denison | R. W. Clark | R. E. Rettger | Carey Croneis |
| 1944 | Dallas | Ira H. Cram | W. B. Weeks | R. E. Rettger | Gayle Scott |

[1] From March, 1929, to March, 1932, the corresponding office was *first vice-president*.
[2] From March, 1929, to March, 1932, the corresponding office was *second vice-president in charge of finances*.
[3] From March, 1929, to March, 1932, the corresponding office was *third vice-president in charge of editorial work*.
[4] Died, November 25, 1927.
[5] Died, January 3, 1940.
[6] Died, January 10, 1939.
[6a] Died, June 30, 1944.
[7] Died, July 9, 1943.
[8] Died, November 5, 1932.
[9] Died, January 29, 1940.
[10] Died, December 13, 1943.
[11] Died, July 5, 1940.
[12] Died, July 8, 1939.

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

### FOR ACTIVE MEMBERSHIP

Sheridan A. Berthiaume, Houston, Tex.
John C. Miller, W. W. Patrick, Oscar L. Bocock

Sam Glen Billings, Oklahoma City, Okla.
Garth W. Caylor, John Janovy, J. M. Clark

Ralph David Chambers, Midland, Tex.
Cary P. Butcher, George R. Gibson, Bernerd A. Ray

Aimer Floyd Childers, Jr., Houston, Tex.
H. E. Minor, P. B. Leavenworth, Marcus A. Hanna

Charles Hewitt Dix, Pasadena, Calif.
Herbert Hoover, Jr., John P. Buwalda, Barthold W. Sorge

James Cornelius Gilbert, Cody, Wyo.
E. W. Krampert, R. W. Sherman, J. R. Pemberton

Joseph Baldwin Koenig, Midland, Tex.
Hal P. Bybee, Berte R. Haigh, George R. Gibson

Hubert Lowell Popenoe, Jr., Bakersfield, Calif.
D. E. Taylor, Arthur S. Huey, Arne Junger

James Richardson Randolph, Houston, Tex.
W. Hafner, F. Goldstone, L. K. Mower

Jackson Bennett Sparks, Newark, Ohio
Reginald G. Ryan, J. R. Lockett, Daniel A. Busch

Ralph Henry Wilpolt, Albuquerque, N. Mex.
Robert L. Bates, Georges Vorbe, Hugh D. Miser

### FOR ASSOCIATE MEMBERSHIP

John Robert Berg, Wichita, Kan.
John W. Inkster, H. E. Summerford, A. C. Trowbridge

Thomas Brown Campbell, Tyler, Tex.
Lynn L. Harden, Pat Meholin, Parker A. Robertson

Robert Sinclair Dietz, Westfield, N. J.
F. W. DeWolf, Harold R. Wanless, F. M. Van Tuyl

Harvey F. French, Denver, Colo.
C. E. Dobbin, William B. Kramer, Gaylord G. Frazier

Ross Henry Ley, Fort Worth, Tex.
C. W. Studt, T. E. Weirich, Walter R. Berger

Bonnie Enerud McCosh, Midland, Tex.
Charles D. Vertrees, E. E. Lindeblad, Warren O. Thompson

Glenn Ernest McKinley, Oklahoma City, Okla.
Charles E. Decker, V. E. Monnett, C. G. Lalicker

### FOR TRANSFER TO ACTIVE MEMBERSHIP

Gerson Herzl Brodie, Abilene, Tex.
E. L. Earl, W. R. Ransone, C. V. A. Pittman

Horace Chesterfield Davis, Wichita, Kan.
A. S. Bunte, Robert S. Clark, Wendell S. Johns
Robert Bowen Kelly, Glendale, Calif.
R. Ten Eyck, Glenn H. Bowes, R. M. Barnes
Robert Edmond LeBlond, Midland, Tex.
Ronald K. DeFord, George R. Gibson, Cary P. Butcher
David Taylor Richards, Wichita Falls, Tex.
Hubert E. Bale, Richard W. Camp, R. W. Laughlin
Sam H. Stith, Jr., Evansville, Ind.
Stanley G. Elder, Daniel J. Jones, Arthur C. McFarlan

(*Continued on page 252*)

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## FOURTH WAR-TIME CONFERENCE CANCELLED

*To the members and associates of The American Association of Petroleum Geologists:*

In compliance with the request of the Honorable James F. Byrnes, the executive committee has cancelled the fourth war-time conference of the Association scheduled to be held at the Mayo Hotel, Tulsa, Oklahoma, March 20–22, 1945. In accordance with the constitution and by-laws of the Association, a corporation, the annual meetings of the business committee and of the Association will be held at the Mayo Hotel, Tulsa, Oklahoma, March 27, 1945. Only necessary Association business will be transacted.

IRA H. CRAM
Chairman of the executive committee

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At its annual meeting on January 4, 1945, the West Texas Geological Society, Midland, Texas, elected the following officers for the year 1945: president, F. H. MCGUIGAN, Lion Oil Refining Company; vice-president, LEO NEWFARMER, Shell Oil Company, Inc.; secretary-treasurer, ALAN B. LEEPER, Honolulu Oil Corporation.

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MAX W. BALL delivered the Bownocker lectures before the department of geology and the Society of Sigma Xi, at the Ohio State University, on January 15 and 16. On January 15 he spoke on "The Search for Oil," on January 16 "The Athabaska Oil Sands" and "An Adventure in Statecraft." The last lecture was an account of the accomplishments of the petroleum industry in coöperation with the Government at the unprecedented task of fueling the war.

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### GEOLOGISTS NEEDED IN FEDERAL SERVICE

A new announcement of interest to geologists has just been issued by the Civil Service Commission. Throughout the war period there has been a continuing opportunity for persons with geological experience or training. For this reason the Commission has issued the current announcement to replenish its lists of eligible persons who are interested in this type of work. The positions to be filled pay $2,433 a year including the amount for overtime.

Three years of technical experience in the field of geology are required, unless appropriate college study is substituted therefor. The experience must have included work in one of the following branches of geology: stratigraphy; structural geology; paleontology mineralogy; petrology; or the geology of mineral deposits, ground waters, or petroleum.

If substituting education for experience, applicants must show completion of a full course of college study leading to a bachelor's degree including at least 30 semester hours of study in geology. A combination of experience and education may also be qualifying.

There are no age limits for these positions and no written test will be given. Full information and application forms may be secured at first- and second-class post offices, from the Commission's regional offices, or direct from the U. S. Civil Service Commission, Washington 25, D. C.

Appointments to Federal positions are made in accordance with War Manpower Commission policies and employment stabilization programs.

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## PROPOSED GEOLOGICAL INSTITUTE OF AMERICA[1]

A. RODGER DENISON[2]
Tulsa, Oklahoma

At the annual meeting of The American Association of Petroleum Geologists at Denver in April, 1942, Carey Croneis gave an address on "Geology in War and Peace."[3] In this address Croneis " . . . contended that the profession of geology does not occupy as high a position in national esteem, and thus in fundamental national utility, as its potential importance warrants." To correct this condition he made " . . . several suggestions for the good of the science." The first of these was—"Organize an American Geological Association to which each geologist, each person fundamentally interested in the subject, may belong regardless of field of specialization, or prime professional application." Three other suggestions were made, the last of which has a very close relationship to the first and is as follows—"Inaugurate and consistently maintain a unified, vigorous, and yet dignified public relations program."

This address stimulated much discussion during the next several months, which was further augmented by an address—"Geological Warfare"—presented by Croneis before several of the local affiliated geological societies. There developed a desire among a number of the membership of The American Association of Petroleum Geologists and other societies to have a meeting called at which the idea of an American Geological Association could be discussed.

In response to this growing sentiment, and in line with Croneis' idea that "The American Geological Association should be sponsored by the present officers of the major geological societies," Fritz L. Aurin, then president of the A.A.P.G., sent a letter in March, 1943, to all national and local societies which had geology as their principal interest. This letter invited each society to send a representative to a meeting to be held in Fort Worth on April 10, 1943 (on the day following the close of the A.A.P.G. annual meeting).

Every society replied to this letter and the majority of them sent representatives. These representatives, together with many other geologists having an interest in the subject (total of more than 100) heard Croneis give a review of his ideas of the year before and outline a framework of the plan for organizing an American Geological Association.[4]

[1] Manuscript received, January 11, 1945.

[2] Representative of the Association at the New York meeting.

[3] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (July, 1942), pp. 1221–49.

[4] "Geological 'Union Now'," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27 (July, 1943), pp. 1001–07.

At this meeting A. I. Levorsen was selected as temporary chairman and after several hours of lively and constructive discussion two resolutions were adopted as follows.

(1) Resolved that it is the concensus of this meeting that the geological organizations can contribute more effectively to the service of society by sponsoring a new association which shall have for its purpose the coordination and integration of the efforts designed to demonstrate universal applications of the earth sciences.

(2) Resolved that the chairman of this meeting shall appoint a committee of five composed of representatives of societies here present, who shall formulate a statement of the fundamental purposes of the proposed association for the advancement of earth sciences and a suggested form of organization to accomplish these purposes, and that the statement and plan be transmitted to each of the interested societies with the request that they appoint official representatives to attend an organization meeting to be held at the call of the Chairman of this meeting at the earliest practicable date.

The following committee was named pursuant to the foregoing resolution 2.

Lincoln R. Thiesmeyer, chairman
A. Rodger Denison
W. B. Heroy
W. Taylor Thom, Jr.
Paul Weaver
Carey Croneis, consultant
Paul H. Price, ex-officio
A. I. Levorsen, ex-officio

The work of this committee was summarized by Levorsen as follows.

This committee (with the exception of Thom, Weaver, Croneis, and Price, who were unable to be present but who later, by correspondence, concurred in the action taken) met for three days, August 20, 21, and 22, 1943, in Chicago. The committee, which was assisted throughout the meeting by the active participation of Fritz L. Aurin, Fred H. Lahee, Ira H. Cram, and Theron Wasson, discussed the various possible ways of achieving the desired results. In general, the methods suggested were:

(1) Changing the Constitution of one of the existing societies in order to expand its activities;
(2) Organization of an entirely new society consisting of individual members, probably with requirements for membership less in geological achievement than in any of the present national organizations; and
(3) Organization of a federation, an institute, or a council in which the membership shall be in either:
  (a) the national geological organizations;
  (b) national and local geological organizations.

The committee unanimously agreed that the best method would be a federation or council of the national earth science societies whose members have professional standing. This is somewhat along the lines which the physicists and biologists have united their societies. The advantages of such a plan over the others are as follows:

(1) It does not require the joining of a new association, institute or society by the individual;
(2) If all the local societies were included in the governing board, when such a board met it would be a large and cumbersome group on the scale of an annual convention. By confining the membership to the national organizations, with the work done by a board of directors of not over 15 or 20 persons, a means is provided of efficiently and economically carrying out the aims of geology. The proposed organization is a working group.
(3) Most geologists, geophysicists, and engineers, who are members of local societies are also members of one or more of the national organizations and they will be represented through such membership equally as well as if the local societies were included. Other interested persons not so represented may be reached through some more general and popular publication than the present technical journals depending on the action of the governing board.

TENTATIVE CONSTITUTION

The result of the committee meeting in Chicago was the drawing up of a tentative constitution in accordance with the conclusions that a council or federation of geological societies was the most practical and efficient manner of handling the problem. The constitution which was drawn, deliberately gives the council, through its directors, broad and flexible powers because it is not possible at this time to define the activities or actions which may at some future time best serve the interests of geology.

Levorsen was instructed by this committee to communicate the results of the committee's findings to the several geological organizations who were or might be interested in their deliberations. On April 3, 1944, Levorsen sent a report and the tentative constitution as prepared by the committee to the secretary of the following geological societies.

American Association of Petroleum Geologists
American Geophysical Union
American Institute of Mining and Metallurgical Engineers
Geological Society of America
Mineralogical Society of America
Paleontological Society
Seismological Society of America
Society of Economic Geologists
Society of Economic Paleontologists and Mineralogists
Society of Exploration Geophysicists
Society of Vertebrate Paleontologists

The following action was requested of each society to whom the report was sent.

(1) Officially study the proposed constitution and its implications to their organization.
(2) Advise of any suggestions or changes which should be made to comply with their constitution or the way in which they transact their business.
(3) Advise of the procedure which will be followed and the time required for their governing body to approve in principle, but without final commitment, the tentative constitution and to authorize an official representative to meet with the representatives of the other Founder Organizations in an exploratory constitutional convention where a final constitution may be drawn in which the interests of each organization will be considered. This proposed final constitution would then be re-submitted to each of the prospective Founder Societies for final approval.

It required considerable time for the several societies to comply with the action requested in the letter so that it was not until September 20, 1944, that a call was issued for a meeting of the official representatives of the several societies, at which the tentative constitution could be examined and rewritten to conform with the many comments and criticisms which had been made.

Sixteen official representatives of eight societies and six observers met in New York at the headquarters of the Geological Society of America on October 22 and continued their meeting into October 23. In all, a total of 22 geologists took part in the discussions during these two days. This was a "constitutional convention" and the primary business conducted at this meeting was the rewriting of the tentative document which had been submitted to these societies.

Lincoln R. Thiesmeyer, chairman of the committee appointed at Fort Worth and secretary (by election) of the meeting in New York, prepared a report and summary of the ideas of those favoring the establishment of the American Geological Institute. The following information is taken from his letter of November 15, 1944.

THE NEEDS FOR THE ORGANIZATION

(1) The need for an organization which will represent authoritatively all the fields of geology and all professional workers in the multiplying specialties of geologic science and technology on problems of common interest or of public service.
(2) The need to provide a simple and efficient mechanism for coordinating the efforts of existing organizations in these fields on matters of common interest. It is obvious that the service of the earth sciences to society can be immeasurably increased by such cooperative effort.
(3) The need for both wider and fuller understanding among intelligent people of the meaning and especially of the usefulness of earth sciences. The most striking example of this need, one that has impressed many geologists deeply, is the failure of our military leaders to call upon geological sciences for a greater application of their special disciplines in the present war.

After a thorough exploration of several alternative proposals for meeting these needs the representatives present voted that establishment of a federation of independent national societies, each retaining its complete autonomy while cooperating with others for their mutual benefit, holds greater promise of success than creation of a new society that would require membership by individuals, or than the modification of an existing organization. Faith in this conclusion is strengthened by the striking progress of just such federation in two of our sister sciences—the Union of American Biological Societies, founded

nearly twenty-five years ago, and the American Institute of Physics, now in its fourteenth year.

### SCOPE OF THE ORGANIZATION

At the New York meeting there was extensive discussion on the specific objectives and character of such an organization for the earth sciences. There was general agreement that it should have the broadest possible scope, encompassing in its objectives the entire field of pure and applied geology. It should become the means of implementing a pledge of cooperation between groups having diversified interests but a common denominator in the parent science, geology.

Obviously a list of specific objectives would reflect and might even be to some extent a composite of the objectives of the constituent organizations. The list should, however, be more comprehensive than the dominant objectives of any of the individual societies. Broadly stated, the objectives of the proposed new organization might include all those here listed.

### LIST OF POSSIBLE OBJECTIVES

To coordinate effort among all organizations, institutions, societies and agencies functioning the field of earth sciences

To improve and extend the application of geologic science to the development of mineral resources and to human industry and welfare

To promote public education in geology and in its usefulness to society

To encourage and promote research and investigation in earth sciences and in other sciences contributing to a knowledge of the earth and of its history

To serve as a single, unifying and authoritative voice for all branches of geologic sciences in relation with government, in military circles and to the general public

To encourage closer relations between geology and the other sciences

To improve the education and increase and improve the supply of geologists, and other professional groups engaged through study, research, teaching or application in either pure or applied geology

To increase and improve the supply of competent teaching personnel in all fields of earth sciences

To become a center of information and counsel to all agencies interested in procuring the services of men trained in earth sciences

It is thought that the degree of emphasis to be given to any one or any combination of these goals, and the specific means to be taken for achieving them, should be determined by the Institute's board of directors, rather than by the group at the constitutional convention. In this way the member organizations can control both the tenor and the tempo of the program. This control should be exercised by each organization on an equal basis, regardless of the size of its individual membership or the stature of its treasury. This is desirable because extensive overlapping of membership between our societies makes true equality of numerical representation almost impossible.

All are agreed that in attempting to carry out these purposes the new organization should utilize existing machinery wherever feasible and should seek diligently both to avoid and to eliminate duplication of effort and expenditure. This means operating to a substantial degree through the member organizations. Nevertheless, the Institute should also initiate all new activities which the board finds are for the common good.

For efficient operation it should have a simple organizational pattern and should engage competent full-time personnel to carry out the policies of its governing group. This is the only assurance of that continuity of effort, that commonly is the difference between noble intentions and real achievements.

To do this on a scale merited by the urgency of the need, consistent with the dignity of the professional societies represented, and inspiring confidence both internally and in the public mind, calls for substantial financing. Therefore, the Institute must have the power to solicit and receive funds. A strong sentiment was expressed that financing of the proposed Institute should not be undertaken by the member societies through dues or commitments made as an obligation of membership, but should be procured through action

of its own governing body after it has been formally created. To carry on the program for the first year or two it may be desirable to secure voluntary contributions from interested individuals or groups. There is no reason to believe, however, that its directors will not be successful in finding the necessary funds for self support if they develop a program properly conceived, carefully controlled and appropriately presented. On the contrary, the success of the American Institute of Physics in obtaining ample funds from foundations and from industry demonstrates the possibility.

The constitution of the proposed American Geological Institute is given in full here. It is the result of nearly 2 years of work, study, and deliberation by a widely diversified group of geologists.

## CONSTITUTION

### ARTICLE I—NAME

The name of this organization shall be the American Geological Institute.

### ARTICLE II—PURPOSE

The purpose of this organization is the advancement of geology in all its branches by providing an agency for the cooperation of non-profit organizations active in the fields of pure and applied geology.

### ARTICLE III—MEMBERSHIP

The following organizations are eligible for initial membership in the Institute.

American Association of Petroleum Geologists
American Geophysical Union
American Institute of Mining and Metallurgical Engineers
Geological Society of America
Mineralogical Society of America
Paleontological Society
Seismological Society of America
Society of Economic Geologists
Society of Economic Paleontologists and Mineralogists
Society of Exploration Geophysicists
Society of Vertebrate Paleontology

Other non-profit organizations of national scope may be admitted to membership by the approval of two-thirds of the member organizations.

### ARTICLE IV—BOARD OF DIRECTORS

The control and management of the affairs of the Institute shall be vested in a Board of Directors consisting of two Directors designated by each member organization.

The Directors shall be designated for a term of two years, except that initially one Director from each member organization shall be designated for one year. In case of a vacancy the member organization concerned shall make a new designation to complete the unexpired term. For purposes of determining the terms of Directors, a year shall be construed as the period extending from the close of one annual meeting to the close of the next.

Three Directors-at-large may be chosen annually by the Board of Directors to serve for one year as additional regular members of the Board.

### ARTICLE V—OFFICERS

The officers of the Institute shall be a President, a Vice-President, and a Secretary-Treasurer, who shall be elected annually by the Board of Directors from among its members. They shall take office at the close of the meeting at which they are elected. The President, or in his absence, the Vice-President, shall preside at meetings of the Board of Directors. The duties of the officers shall be those usually devolving upon such officer, except as may be determined by the Board of Directors.

ARTICLE VI—MEETINGS

The annual meeting of the Board of Directors for the election of officers and for the transaction of such other business as may properly come before the meeting shall be held in December or January at such time and place as the President may designate. Directors representing two-thirds of the member organizations shall constitute a quorum, and a majority vote of the Directors present shall be required for the transaction of business. A member organization may designate alternates for any of its Directors unable to attend.

ARTICLE VII—EXECUTIVE COMMITTEE

There shall be an Executive Committee of the Board of Directors, which shall consist of the President, the Vice-President and the Secretary-Treasurer of the Institute.

The Executive Committee shall be charged with the conduct of such business as may be delegated to it by the Board of Directors and shall have authority to act for the Board in the interim between meetings of the Board to such extent as the Board may authorize.

With the prior approval of the Board of Directors, the Executive Committee may establish a headquarters office and employ qualified personnel for conducting the business of the Institute.

ARTICLE VIII—OTHER COMMITTEES

The Board of Directors shall have the power to establish other committees, appoint their members and assign their duties. The members of such committees may or may not be members of the Board. The term of each such committee, unless otherwise specified, shall expire at the close of the next annual meeting of the Board following the appointment of the committee.

ARTICLE IX—FINANCES

The Institute shall have the power to solicit and receive funds. The Board of Directors shall have control of the management and disbursement of the funds of the Institute.

ARTICLE X—AMENDMENTS

Amendments to this Constitution may be proposed in writing to the Board of Directors by any Director. Upon at least thirty days' notice, they shall be considered by the Board of Directors, and, if approved, shall become effective upon ratification by two-thirds of the member organizations.

ARTICLE XI—RULES AND REGULATIONS

The Board of Directors may adopt such rules and regulations as it deems necessary or desirable for the conduct of the affairs of the Institute.

ARTICLE XII—RESIGNATION

Any member organization may resign by giving written notice to the President of its withdrawal from the Institute, and thereupon its membership and the terms of office of the Directors designated by it shall terminate.

ARTICLE XIII—RATIFICATION

This Constitution shall become effective upon its ratification by seven of the organizations listed in Article III.

In the form here presented the constitution was approved by the representatives of eight national geological organizations. It is now referred back to each of these eight organizations for consideration by the membership and officers of these organizations. This constitution is now before the membership and officers of The American Association of Petroleum Geologists for their consideration. Ratification by this organization and six others named in the constitution will activate the American Geological Institute.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 29, NO. 2 (FEBRUARY, 1945), P. 246

# MEMORIAL

## GERHARD HENNY

1890–1944

Gerhard Henny was born in Batavia, Java; however, his family moved to Holland when he was 3 years of age. He obtained his early schooling in Amsterdam following which he attended the Polytechnic University of Zurich, Switzerland. He obtained a Chemical Engineer degree in 1912 and followed this with a year of post-graduate work in mineralogy and petrography under Professor Grubenmann. In 1913 he enrolled at the University of Lusanne, Switzerland, for post-graduate work. His thesis work in the Tyrol was interrupted by the outbreak of World War I and it was 1917 when he obtained his Doctor of Philosophy degree from Lusanne.

The following year Dr. Henny spent in an investigation of the oil possibilities of Italy and Sicily. Upon his return to Holland in 1919 he received the appointment of assistant professor at the University of Delft. In 1920 he returned to the Dutch East Indies where he undertook geologic mapping on the Island of Boeroe. Upon completing this work he returned to Europe and spent several months at Sorbonne working up the results of the Boeroe investigation.

In 1922 Dr. Henny came to the United States and entered the employ of Roxana Petroleum Corporation at Ponca City, Oklahoma. His first assignment was in southern Kansas where he did geologic mapping in the vicinity of the Eldorado and Augusta oil fields. The following year he was transferred to the Shell Oil Company in California with headquarters in Bakersfield.

During the following 7 years from 1923 to 1930 Dr. Henny worked in many parts of the San Joaquin Valley and acquired a wide circle of friends and acquaintances throughout the oil fraternity of California.

In 1930 he opened an office as consulting geologist in Los Angeles. In this capacity he undertook geological investigations in California, Arizona, and Alaska.

Dr. Henny was the author of several geologic papers on the Alps, the Island of Boeroe, and the San Joaquin Valley, California, and in addition published a paper on evolution. He was a member of the geologic societies of Italy, France, Switzerland, and Holland as well as the American Association of Petroleum Geologists and the American Institute of Mining and Metallurgical Engineers.

Dr. Henny will be missed by his wide coterie of friends and acquaintances for it can truly be said that life was never dull when Gerhard was around. He died, September 9, in San Pedro, California, after a brief illness.

L. M. CLARK

SHELL OIL COMPANY OF CANADA LIMITED
CALGARY, ALBERTA
December, 1944

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 29, NO. 2 (FEBRUARY, 1945), PP. 247-252

# AT HOME AND ABROAD

## CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

STEWART BARCLAY, of the Phillips Petroleum Company, Bartlesville, Oklahoma, has been transferred to the Phillips Venezuelan Oil Company at Caracas, Venezuela.

WILLIAM S. PIKE, JR., of the Shell Oil Company, Ind., has been transferred from Houston, Texas, to 1056 O'Sullivan Building, Baltimore, Maryland, where he is acting district geologist.

HEWLETT A. RUSSELL has opened his own office as consulting geologist in the McCain Building, Graham, Texas.

ERNST KUNDIG, formerly with Diadema Argentina S. A. de Petroleo at Buenos Aires, is with Cia. de Petroleo Shell de Colombia, Bogota, Colombia.

R. E. STEWART, formerly of Ventura, California, is with the Oregon State Department of Geology and Mineral Industries, 702 Woodlark Building, Portland, Oregon.

MARION HARBIN FUNK, district geologist for the Sun Oil Company at Midland, Texas, since 1937, died in Midland, December 30, from a heart attack. His age was 46 years. Funk was a graduate of the University of Nebraska (1926). His early work was for the Gulf Oil Company in Venezuela and later he gained wide experience in the Gulf Coastal Plain, the Mid-Continent, and the southern Permian basin of the United States, in the employ of the Louisiana Oil Refining Corporation, the Pure Oil Company, the American Oil Company, and the Sun Oil Company.

W. KENLEY CLARK, of the Superior Oil Company, has moved from Houston to Shreveport to open a district office for his company.

W. K. ESGEN has resigned his position as Gulf Coast division manager of the British-American Oil Producing Company and has opened an office at 503 Mellie Esperson Building, Houston, Texas.

FRANK W. BELL, of the Shell Oil Company, Ind., is president of a new geological society in northern California. His address is 514 Forum Building, Sacramento.

J. M. BUGBEE has moved from Houston, Texas, to Lake Charles, Louisiana. He is a senior explortation engineer with the Shell Oil Company, Inc.

C. W. TOMLINSON, of Ardmore, Oklahoma, spoke on "Natural Resources in Post-War Planning," before the Tulsa Geological Society, January 4. The meeting was held in Terrell Hall, University of Tulsa.

Lieutenant Colonel DONALD F. NEWELL died on December 7, 1944, of wounds received in action in the Southwest Pacific. Before entering the service in April, 1941, he was a geologist with the Phillips Petroleum Company in Corpus Christi, Texas.

Lieutenant Colonel J. D. TOMPKINS, formerly with the Acme Oil and Royalty Company, Midland, Texas, is stationed in India with the India-China Division of the Army Air Forces.

W. R. CANADA is with the Magnolia Petroleum Company at Lake Charles, Louisiana.

J. N. CONLEY is with the Seaboard Oil Company of Delaware at Corpus Christi, Texas.

At a regular supper meeting of the Alberta Society of Petroleum Geologists, January 4, at the Renfrew Club, the Public Relations Branch, Northwest Service Command, United States Army, showed a technicolor film on "The Canol Project." The Society has a membership of nearly 80.

EDWARD D. LYNTON has returned after 21 months with the Foreign Economic Administration, 18 of which were overseas, in French North Africa, Tripolitania, Egypt, and England. The work consisted of rehabilitating the French economy in North Africa, and various engineering problems. Lynton is back with the California Research Corporation, a subsidiary of the Standard Oil Company of California. He is located at the main office, 200 Bush Street, San Francisco.

W. L. WHITEHEAD, who has been in charge of geological exploration for aluminum ores in Haiti, Puerto Rico, the Dominican Republic, Cuba, and Mexico for the Reynolds Metals Company, has recently returned to the Massachusetts Institute of Technology. Discoveries of bauxite made in Haiti by the field parties, which included R. R. SHROCK and FORBES ROBERTSON, are being developed under the direction of CARL SCHMEDEMAN, chief geologist of the Reynolds Mining Company.

PARKER D. TRASK, of the United States Geological Survey, has been appointed professor of geology in the University of Wisconsin. He will enter upon his duties in September, 1945, following completion of his present assignment on war work for the United States Geological Survey.

CHESTER D. WHORTAN has been the Officer in Charge of Aerial Photographic Interpretation for the United States Navy in the Mediterranean area since shortly after the invasions of North Africa. He took part in the invasions of Sicily, Italy, and Southern France. For his work in the invasion of Southern France he was awarded the Commendation of the Secretary of the Navy. On November 17, 1944, he was promoted to the rank of Lieutenant Commander. He has been assigned to permanent duty at the Photographic Interpretation Center, Naval Air Station, Anacostia, D. C., and expects to be located there for a few months. His permanent address remains Box 311, Coudersport, Pennsylvania.

NORMAN L. THOMAS, secretary of the San Joaquin Geological Society, Bakersfield' California, reports the technical program of that society for year 1944 as follows.

January 22, SAM H. KNIGHT, "The Physical Evolution of the Rocky Mountains"
February 16, JACK Q. ANDERSON, "Miocene Stratigraphy of the East and West Sides of East Coalinga Fields"
March 14, F. E. WELLINGS, "Petroleum Geology of the Middle East"
April 11, JOSEPH J. GRAHAM, HERMAN W. WEDDLE, and BURTON R. ELLISON, "Paleocene"
May 9, M. N. BRAMLETTE, "Stratigraphic Relations in the Lower Miocene on the West Side of the Salinas Valley"
June 19, T. P. PENDLETON, "Newly Developed Methods of Making Topographic Maps from Aerial Photographs"
August 17, GLENN H. FERGUSON, "Notes Concerning Florida"
September 20, ARTHUR S. HUEY, "Geologizing in Montana"
October 24, N. L. TALIAFERRO, "Cretaceous and Paleocene of the Santa Lucia Range"
November 14, RALPH E. STEWART, "Paleocene on the West Side of the San Joaquin Valley"
December 20, JOHN H. BEACH and R. STANLEY BECK, "A Discussion of the Areal Distribution and Stratigraphic Position of the Wicker Sand."

There are 107 geologists in the San Joaquin Valley. Members of the Association in good standing in 1944 numbered 74. The average attendance at each meeting was 47. The officers for 1944 were: GLENN H. FERGUSON, chairman; THOMAS K. BOWLES, vice-chairman; NORMAN L. THOMAS, secretary-treasurer. Incoming officers are: GLEN W. LED-

INGHAM, chairman; J. D. CERKEL, vice-chairman; HERMAN W. WEDDLE, secretary-treasurer.

Lieutenant JOHN F. BARNETT, JR., of Palacios, Texas, formerly with the Standard Oil Company of Venezuela, was killed near the Po Valley, in Italy, on October 13, 1944. He was with the 34th Division, United States Army.

F. W. FLOYD, who has been in Venezuela during the past 7 years with the Creole Petroleum Corporation, has resigned to take charge of the new office of the Phillips Petroleum Company of Venezuela at Caracas.

ROSCOE E. SHUTT has been appointed vice-president of the Barnsdall Oil Company in charge of exploration in the Mid-Continent area. Shutt recently resigned his position in charge of exploration for the Shell Oil Company, Inc.

WAYNARD BURTON PERRY, formerly with the Seismograph Service Corporation at Shawnee, Oklahoma, is with the Carr Geophysical Company, 1334 Commerce Building, Houston, Texas.

RAY E. MORGAN has accepted a position with the Socony-Vacuum Oil Company, Inc., Bogota, Colombia.

Lieutenant STAFFORD PARK has returned to the Eastman Oil Well Survey Corporation at Long Beach, California, after serving 2 years in the Navy, including action in combat areas.

W. B. MAXWELL has been elected secretary-treasurer of the Appalachian Geological Society, Charleston, West Virginia, succeeding CHARLES E. STOUT. Both are with the United Fuel Gas Company.

E. F. BOEHMS is employed by the Texas Pacific Coal and Oil Company as district geologist with headquarters at Breckenridge, Texas.

G. L. WHIPPLE, formerly with the Richmond Petroleum Company of Colombia is now with the Richmond Exploration Company of Venezuela, Caracas, Venezuela.

The Fort Worth Geological Society has just completed another successful year. At its annual meeting the following officers were elected for 1945: president, THOMAS B. ROMINE, Sinclair Prairie Oil Company; vice-president, WILLIAM J. NOLTE, Stanolind Oil and Gas Company; and secretary-treasurer, SPENCER R. NORMAND (re-elected), Independent Exploration Company.

### DISTINGUISHED LECTURE TOUR

PHILIP S. SMITH, chief Alaskan geologist of the United States Geological Survey, discussed "Alaska's Potential Oil Resources" before a group of geological societies, largely affiliated with the Association, in January and February.

Dr. Smith was able to bring to his audience a wealth of information and well considered conclusions regarding the oil resources of Alaska, based on his many years of field work and research for the Survey in that territory. His comments on the problems of carrying on exploratory and development work were well illustrated by an excellent series of lantern slides.

In the course of his tour, Dr. Smith addressed the following groups.

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| January | 22 | New Orleans Geological Society at New Orleans |
| | 23 | Mississippi Geological Society at Jackson |
| | 24 | Shreveport Geological Society at Shreveport |
| | 25 | East Texas Geological Society at Tyler |

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|---|---|---|
| | 26 | Dallas Petroleum Geologists at Dallas |
| | 29 | South Texas Geological Society at San Antonio |
| | 30 | Fort Worth Geological Society at Fort Worth |
| | 31 | North Texas Geological Society at Wichita Falls |
| February | 2 | Oklahoma City and Shawnee geological societies at Oklahoma City |
| | 5 | Tulsa Geological Society at Tulsa |
| | 6 | Kansas Geological Society at Wichita |
| | 8 | Rocky Mountain Association at Denver |
| | 9 | Casper Geologists Club at Casper |
| | 12 | Indiana-Kentucky Geological Society at Evansville |
| | 13 | Illinois Geological Society at Olney |
| | 14 | Ohio State College at Columbus |
| | 15 | Pittsburgh Geologists at Pittsburgh |
| | 16 | Michigan Geological Society at Lansing |

JOHN L. FERGUSON, *chairman*
Distinguished lecture committee

---

The Ardmore Oklahoma Geological Society has elected the following officers for 1945: president, STANFORD L. ROSE, California Company; vice-president, MAYNARD P. WHITE, Gulf Oil Corporation; secretary-treasurer, HAMILTON M. JOHNSON, Schlumberger Well Surveying Corporation.

DONALD B. EICHER is with the Standard Oil Company of Egypt, S. A., Box 607, Cairo, Egypt.

E. T. REED is with the Arabian American Oil Company, Bahrein Island, Persian Gulf.

FRANK G. EVANS, JR., research geologist with the Shell Oil Company, Inc., Houston, Texas, has been promoted to be Lieutenant Commander. He is over-seas.

Newly elected officers of the South Louisiana Geological Society, Lake Charles, Louisiana, are: president, MAX BORNHAUSER, Continental Oil Company; vice-president, A. LYNN MORROW, Magnolia Petroleum Company; secretary, BRUCE M. CHOATE, Atlantic Refining Company; treasurer, P. F. HABERSTICK. Members elected to the executive committee are H. E. MCGLASSON and W. R. CANADA, Stanolind Oil and Gas Company.

The Casper Geologists Club, Casper, Wyoming, has elected the following officers: president, C. J. HARES, Ohio Oil Company; 1st vice-president, A. F. BARRETT, General Petroleum Company; 2d vice-president, W. S. MCCABE, Stanolind Oil and Gas Company; secretary-treasurer, R. M. LARSEN, U. S. Geological Survey. T. C. HIESTAND, Cities Service Oil Company, is chairman of the program committee, and W. H. CURRY, Atlantic Refining Company is chairman of the organization committee. A program of technical papers and group activities is being arranged for the year. On January 29 ROSS L. HEATON discussed "The Permian and Pennsylvanian Formations." Weekly luncheons are held at the Townsend Hotel, Casper.

JOHN T. ROUSE, geologist for the Magnolia Petroleum Company, has been transferred from Albuquerque, New Mexico, to the Dallas, Texas, office of the company.

Lieutenant FREDERICK W. (FRITZ) MUELLER has been reported missing-in-action in Luxemborg since December 16, 1944. He has been on duty as an officer with the Field Artillery since March, 1943, and had been over-seas since January, 1944. In civilian life he was district geologist at Houston for the Skelly Oil Company.

Lieutenant LEO C. GRAVIS, of Harlingen, Texas, has been transferred to India.

WALLACE E. PRATT, vice-president of the Standard Oil Company (New Jersey) has resigned, after 30 years of service with the Humble Oil and Refining Company at Houston, Texas, and the New Jersey company at New York. He will continue as a director and a member of the executive committee of the Standard Oil Company. Pratt was the 4th president of the A.A.P.G. (elected at Dallas in 1920).

President EUGENE HOLMAN has announced the election of JOHN R. SUMAN, vice-president and director of the Humble Oil and Refining Company, Houston, Texas, as vice-president and director of the Standard Oil Company (New Jersey).

On February 1 the Houston Geological Society held its regular noon luncheon meeting on the mezzanine floor of the Texas State Hotel. S. W. LOWMAN, of the Shell Oil Corporation of Houston, discussed the "Biolithic Classification of Sedimentary Rocks; Its Possible Value in Future Exploration."

BYRON RIFE, commanding officer of the Kankakee Ordnance Works (TNT) and Elwood Ordnance Plant (loading high-caliber shells, bombs, and mines), Joliet, Illinois, has been promoted to a full colonel.

Lieutenant (jg) LAURENCE BRUNDALL returned to the United States last year after 13 months overseas duty as Photo Interpretation Officer in Hawaii and the Central Pacific. He is attached to the Amphibious Training Command, Pacific Fleet, as instructor in map reading and physiography. His address is Air Support Training Unit No. 1, Naval Air Station, San Diego, California.

President IRA H. CRAM visited the following geological societies in January and discussed affairs of the Association. Corpus Christi, 11th; South Texas (San Antonio), 12th; Fort Worth, 15th; Midland, 17th; and Dallas, 19th.

A. A. CURTICE, vice-president of United Engineering Company, S. A., is located at Room 400, 620 Fifth Avenue, New York City.

D. E. MORGAN has moved from Brisbane, Queensland, Australia, to Bogota, Colombia, South America. He is with Cia de Petroleo Shell de Colombia.

Lieutenant Commander HALE B. SOYSTER, formerly Chief of the conservation branch of the United States Geological Survey, Washington, D. C., died on January 23 at the Naval Hospital, Bethesda, Maryland.

Lieutenant Colonel WALTER B. JONES has returned from Army service and has resumed his duties as State geologist of Alabama.

LOUIS ROARK has resigned as chief geologist of the Margay Oil Corporation to become assistant to vice-president McClintock of the Sunray Oil Corporation, in charge of the land and geological department, Tulsa, Oklahoma.

## ADDITIONAL APPLICATIONS APPROVED FOR PUBLICATION

(*Continued from page 239*)

### FOR ACTIVE MEMBERSHIP

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Ian Laurence Burr, Brisbane, Australia
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Thayer Meredith Gruner, Tallahassee, Fla.
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Harold La Vergn Huffman, Midland, Tex.
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Jane Marie Johnson, Midland, Tex.
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William A. McFadden, Jr., Midland, Tex.
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Robert Charles Stephenson, Laramie, Wyo.
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Capitol Savings and Loan Bldg., Lansing

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

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Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

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Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

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Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon, Y.W.C.A. Cafeteria.

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*Editor* - - - - - - - - - - Roy L. Ginter
U. S. Geological Survey

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Bradford Hotel.

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Stanolind Oil and Gas Company, Box 660

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Luncheons: Noon, fourth Monday, each month, Blackstone Hotel.

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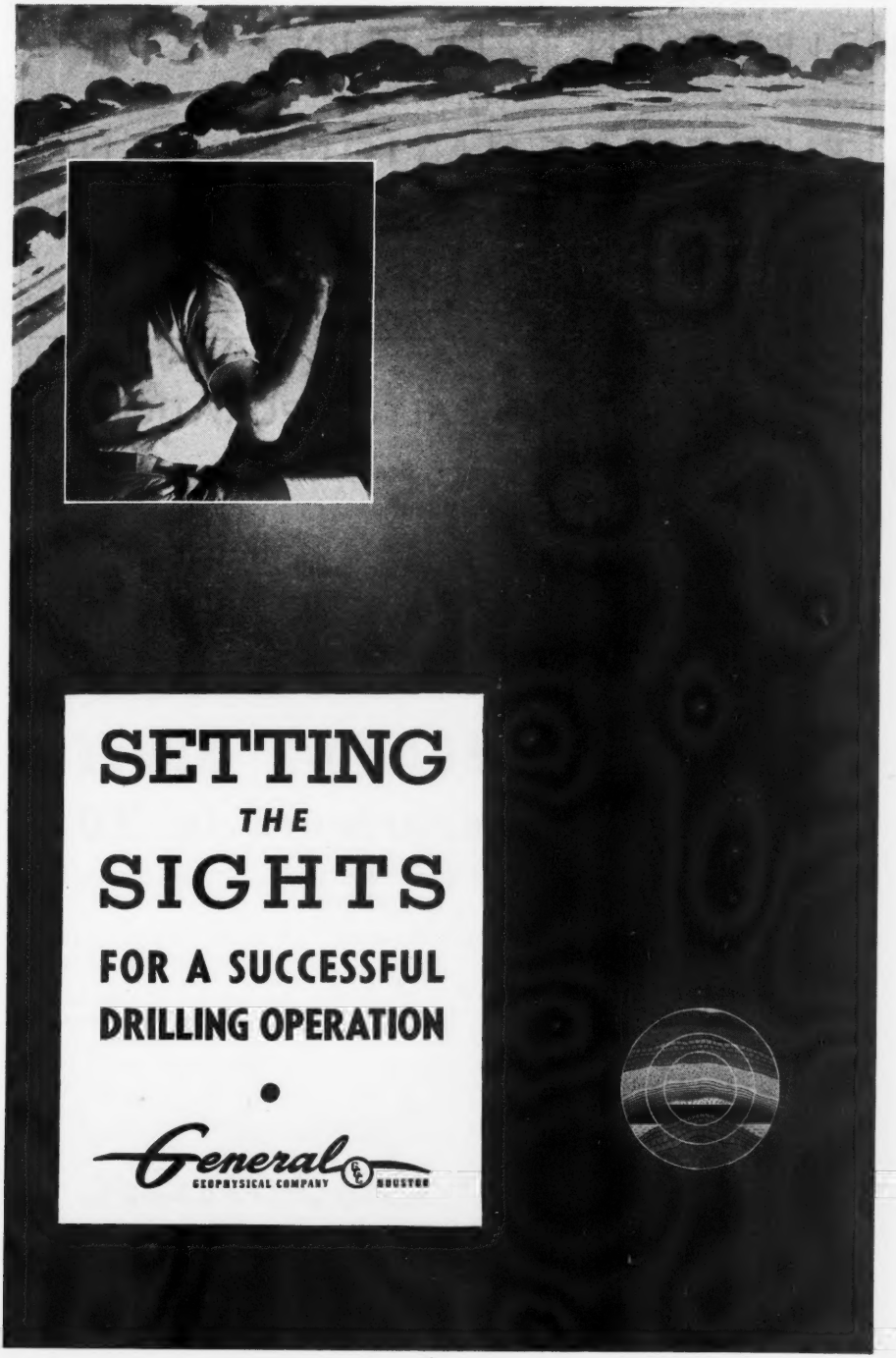
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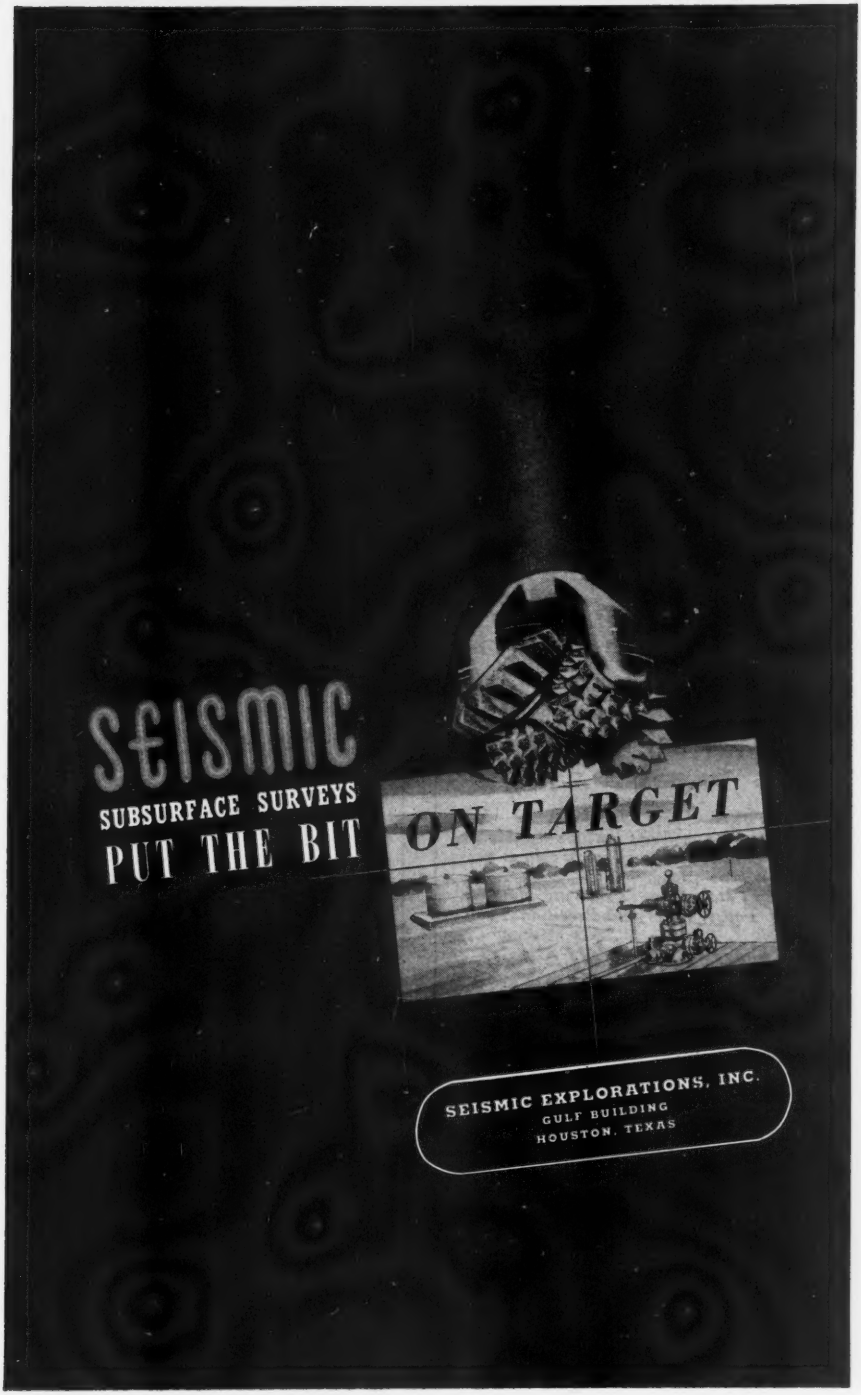
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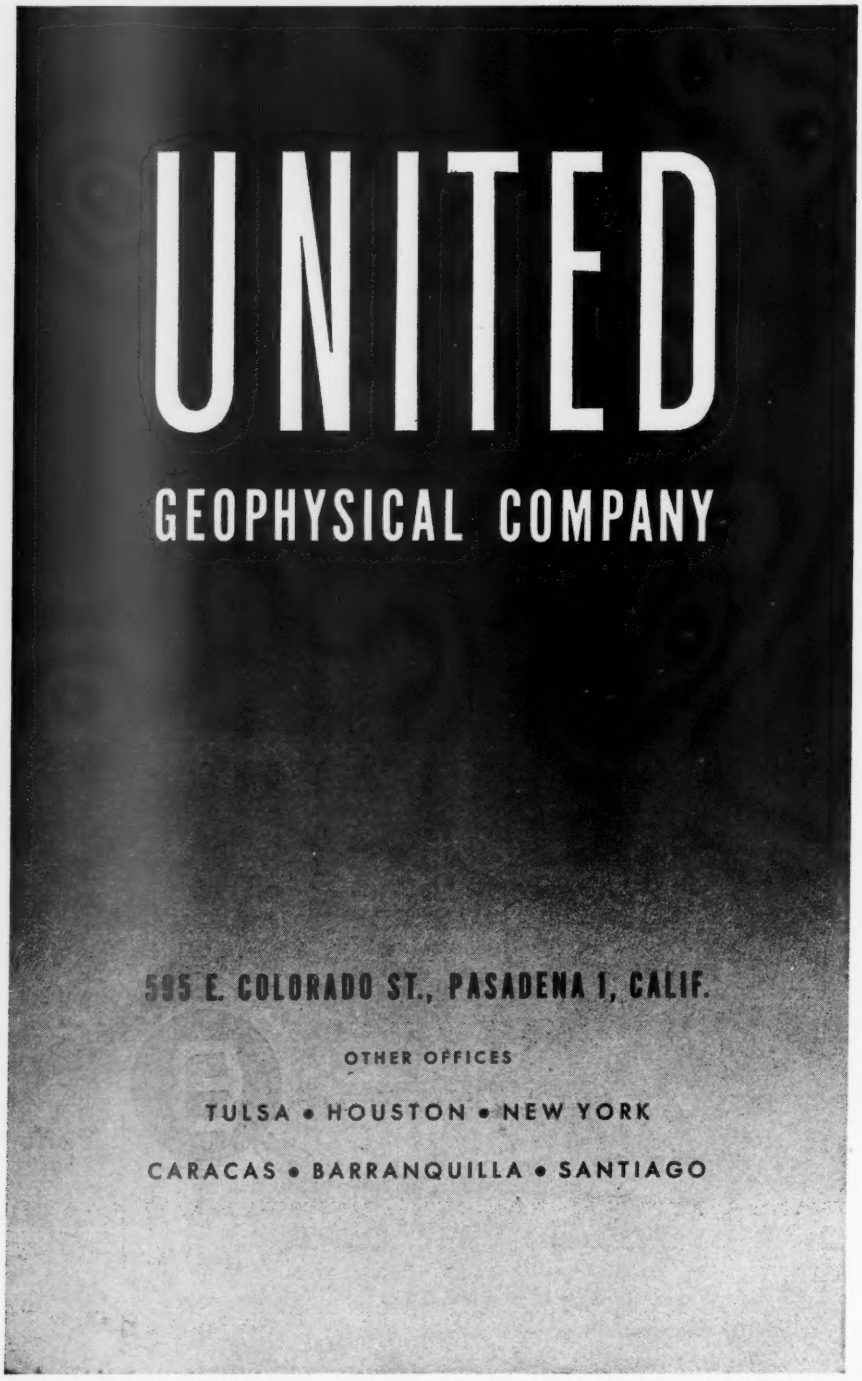
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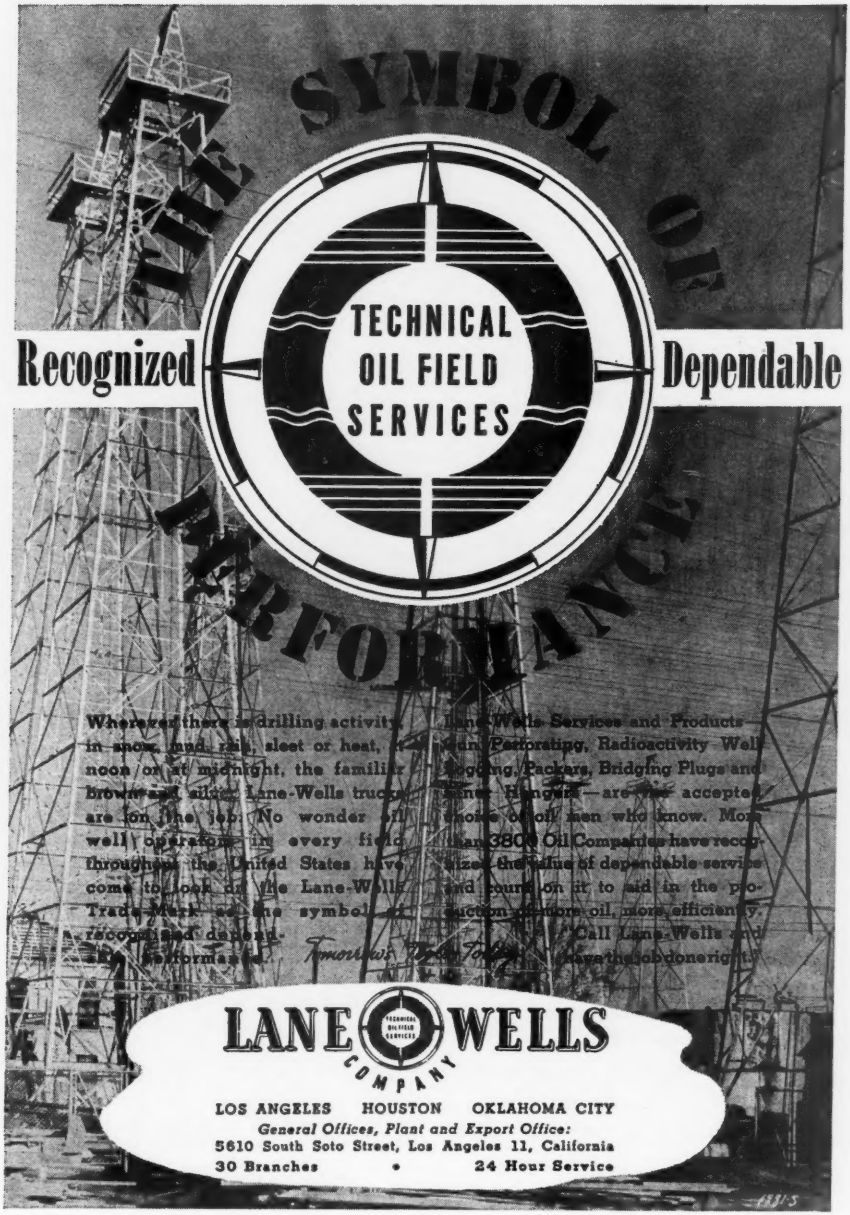
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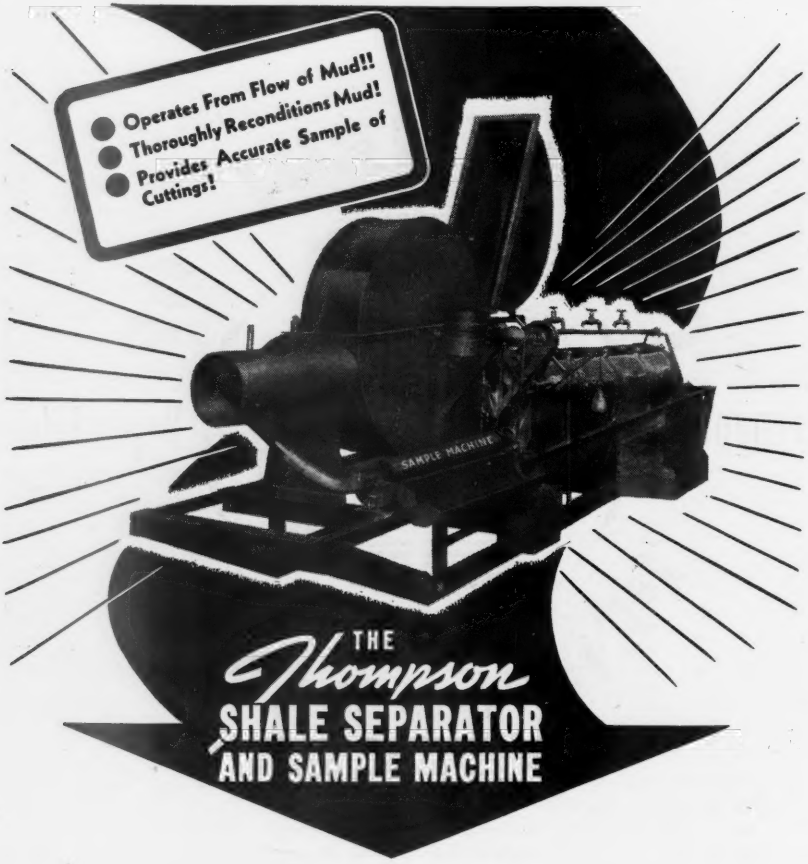


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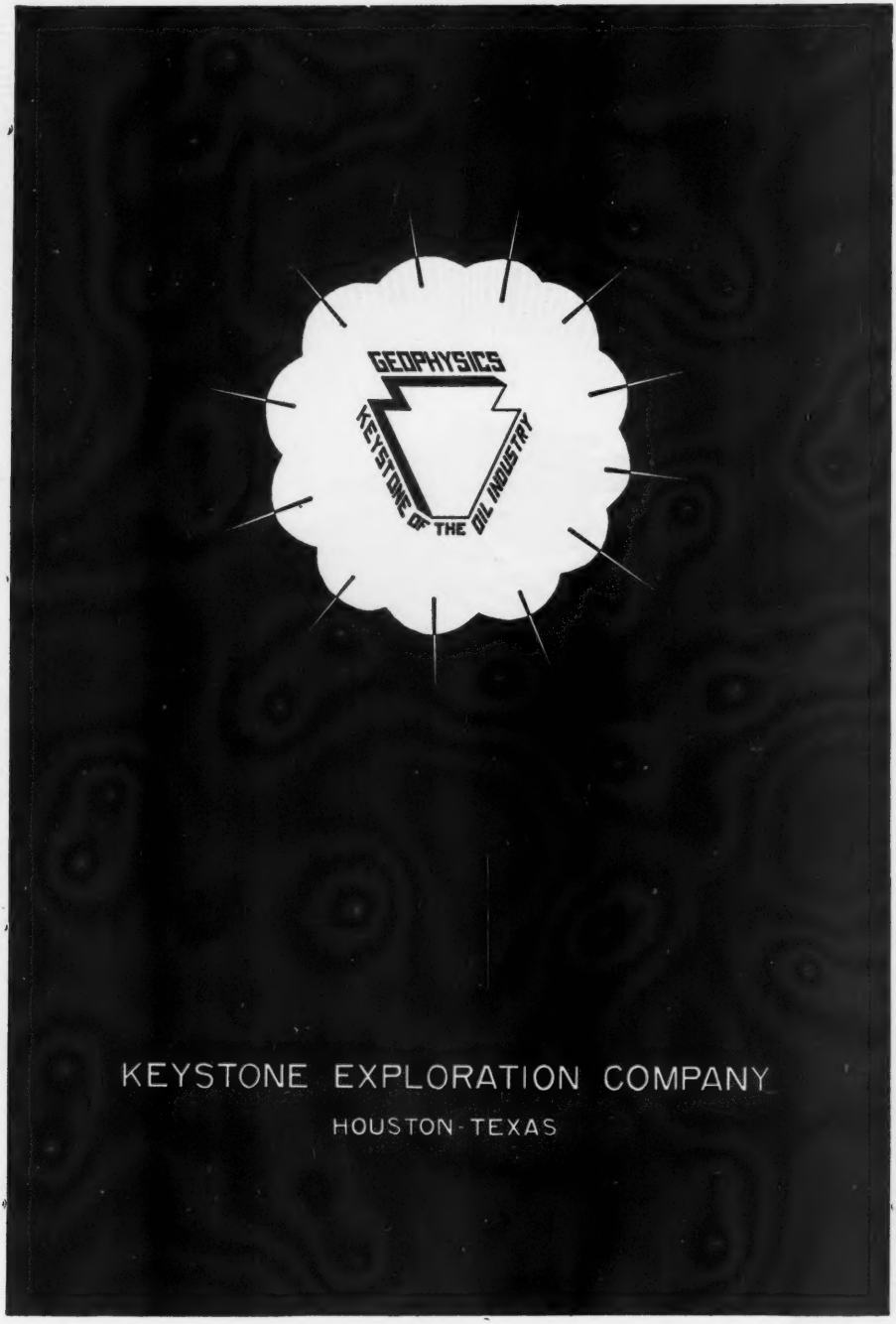
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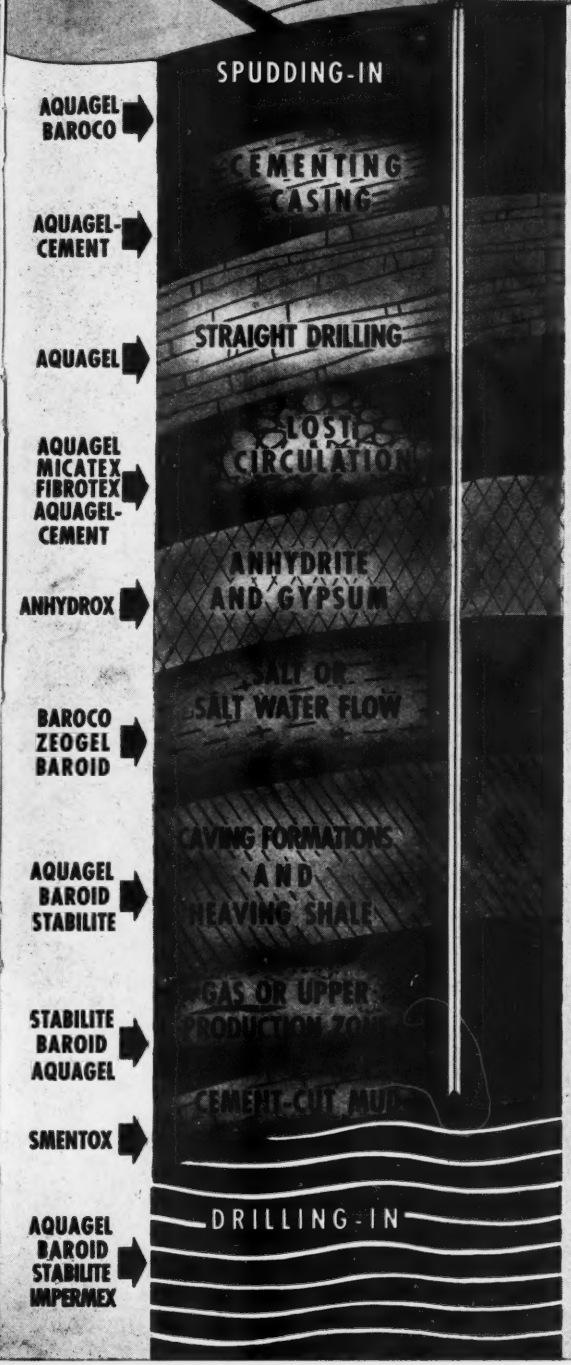


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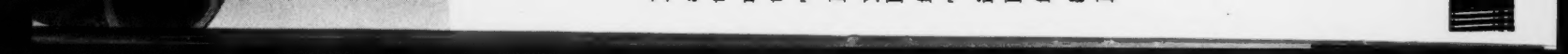

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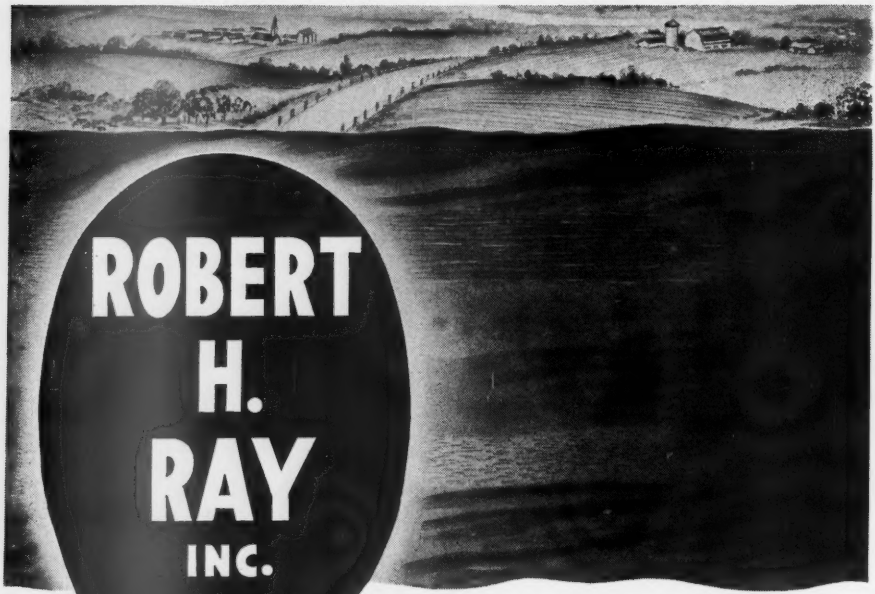


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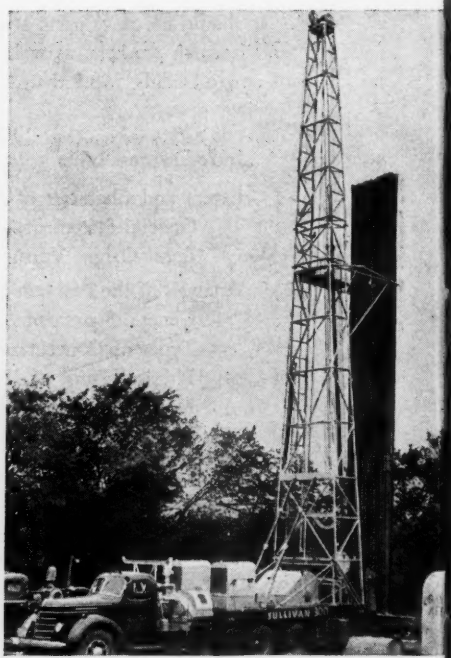

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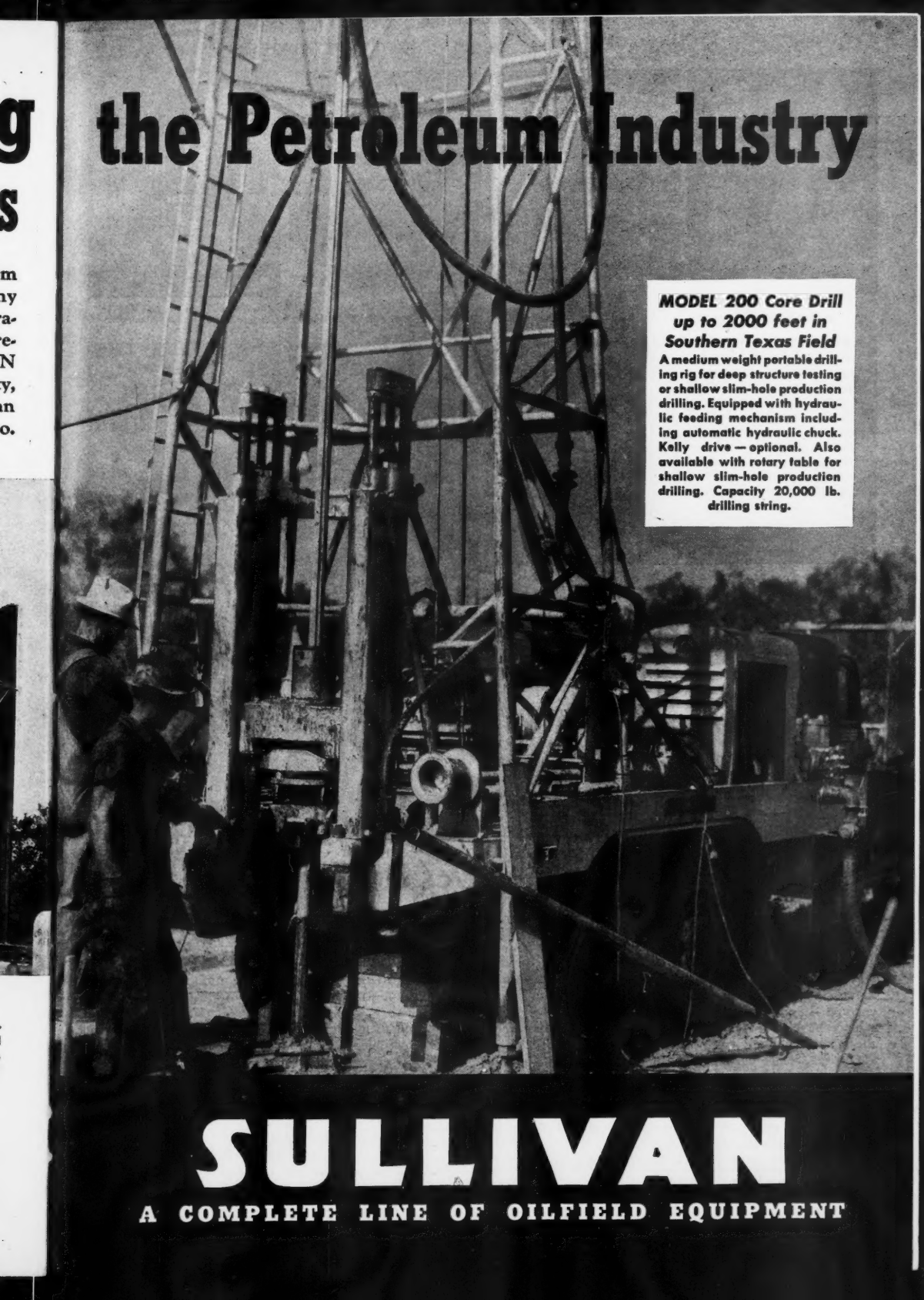
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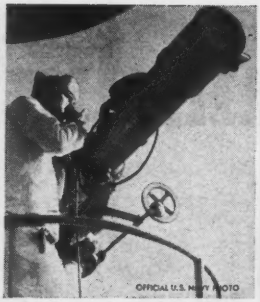

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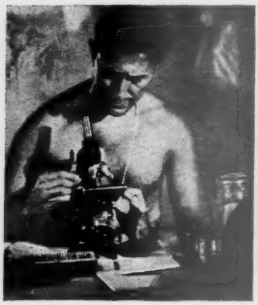

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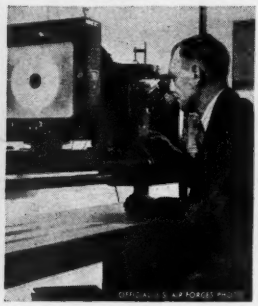

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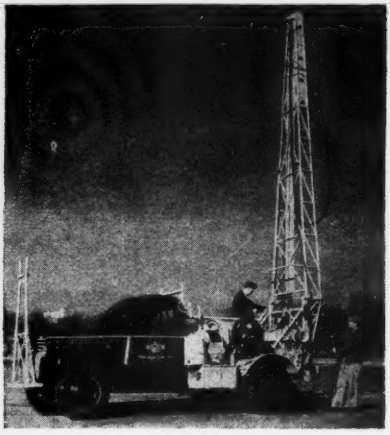

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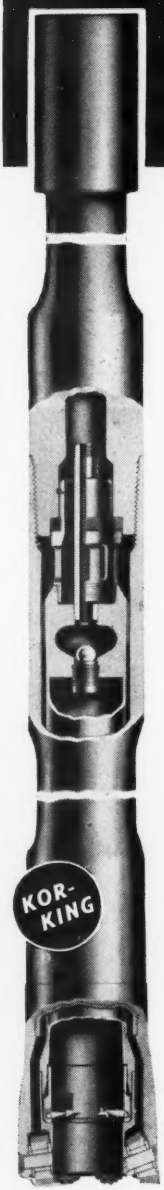


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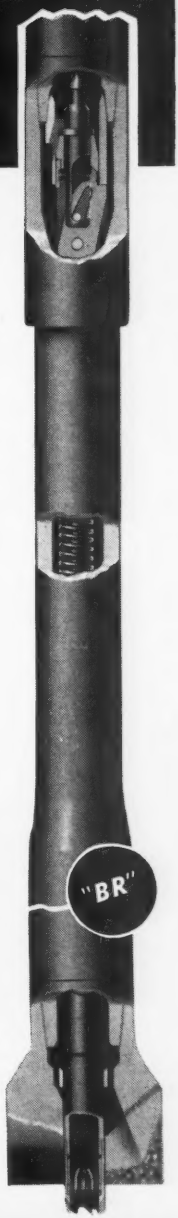


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